L.2.2002-64
University of Alberta Library
0 1620 3415477 1

CHEMISTRY 20

Module 6

Organic Compounds

Learning Technologies Branch

Alberta LEARNING

Library and Archives Canada
Bibliothèque et Archives Canada

Chemistry 20

Module 6

Organic Compounds

Learning Technologies Branch

Alberta LEARNING

Chemistry 20
Module 6: Organic Compounds
Student Module Booklet
Learning Technologies Branch
ISBN 0-7741-0902-5

Cover photo: PhotoDisc, Inc.

This document is intended for	
Students	✓
Teachers	✓
Administrators	
Home Instructors	
General Public	
Other	

You may find the following Internet sites useful:

- Alberta Learning, **http://www.learning.gov.ab.ca**
- Learning Technologies Branch, **http://www.learning.gov.ab.ca/ltb**
- Learning Resources Centre, **http://www.lrc.learning.gov.ab.ca**

The use of the Internet is optional. Exploring the electronic information superhighway can be educational and entertaining. However, be aware that these computer networks are not censored. Students may unintentionally or purposely find articles on the Internet that may be offensive or inappropriate. As well, the sources of information are not always cited and the content may not be accurate. Therefore, students may wish to confirm facts with a second source.

ALL RIGHTS RESERVED

Copyright © 1993, 2001, the Crown in Right of Alberta, as represented by the Minister of Learning, Alberta Learning, 11160 Jasper Avenue, Edmonton, Alberta T5K 0L2. All rights reserved. Additional copies may be obtained from the Learning Resources Centre.

No part of this courseware may be reproduced in any form, including photocopying (unless otherwise indicated), without the written permission of Alberta Learning.

Every effort has been made both to provide proper acknowledgement of the original source and to comply with copyright law. If cases are identified where this effort has been unsuccessful, please notify Alberta Learning so that appropriate corrective action can be taken.

IT IS STRICTLY PROHIBITED TO COPY ANY PART OF THESE MATERIALS UNDER THE TERMS OF A LICENCE FROM A COLLECTIVE OR A LICENSING BODY.

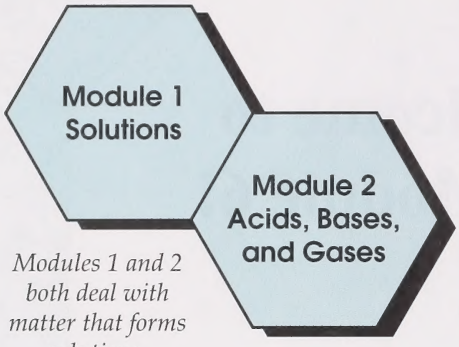
UNIVERSITY LIBRARY
UNIVERSITY OF ALBERTA

Welcome to Module 6!

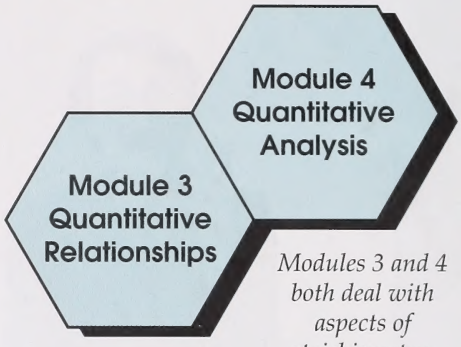
We hope you'll enjoy your study of *Organic Compounds*. Remember, to make your learning a bit easier, several videocassettes and laser videodiscs are referred to throughout the modules. Your textbook *Nelson Chemistry* will also enhance your studies.

COURSE OVERVIEW

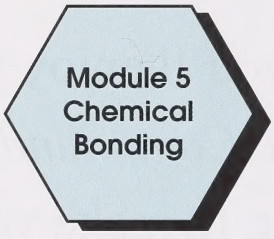
This course contains seven modules. The module you are working in is highlighted in deeper colour.

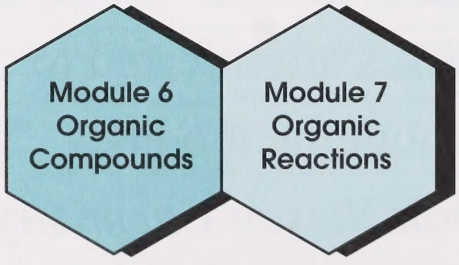


Modules 1 and 2 both deal with matter that forms solutions.



Modules 3 and 4 both deal with aspects of stoichiometry.





Modules 6 and 7 both deal with organic chemistry.

MODULE 6

Contents

Module Overview 1
Evaluation 2

Section 1: Aliphatics 3

Activity 1: What Is Organic? 4
Activity 2: Alkanes 13
Activity 3: Alkenes and Alkynes 22
Follow-up Activities 30
Extra Help 30
Enrichment 33
Conclusion 33
Assignment 33

Section 2: Aromatics 34

Activity 1: Identification and Uses 35
Activity 2: Naming and Structure 40
Follow-up Activities 46
Extra Help 46
Enrichment 49
Conclusion 50
Assignment 50

MODULE 6

Contents

Continued

Section 3: Hydrocarbon Derivatives 51

Activity 1: Organic Halides and Alcohols 52
Activity 2: Aldehydes and Ketones 58
Activity 3: Organic Acids and Esters 63
Activity 4: Amides and Amines 69
Follow-up Activities 75
Extra Help 76
Enrichment 77
Conclusion 77
Assignment 77

Module Summary 77

Appendix 79
Glossary 80
Suggested Answers 80

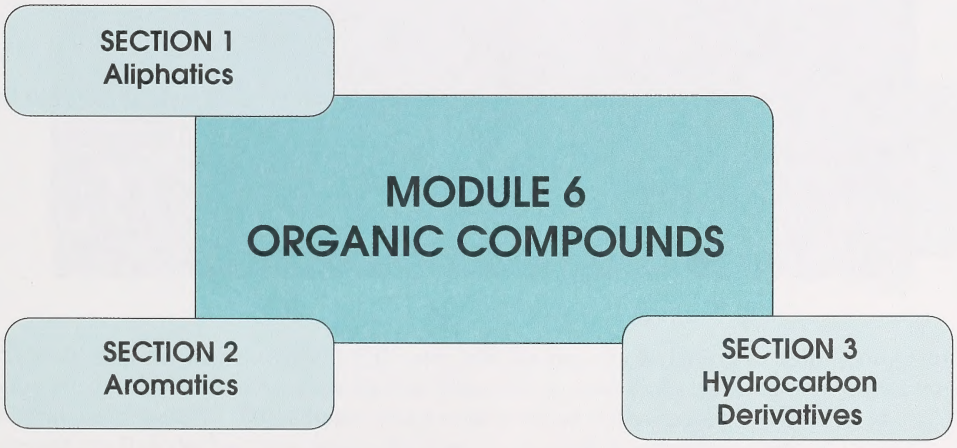
MODULE OVERVIEW

Did you ever consider yourself as a living, walking chemical laboratory? Do you realize that there are probably more organic reactions occurring in your body right now than in all the chemical laboratories in the world? Would you be surprised to know that these same reactions take place under normal conditions in living systems but usually require very high temperatures and pressures in industry?

All living systems depend on chemical reactions for life processes. These may include growth, reproduction, and repair of cells or providing your tissues and systems with energy for all your daily activities. All these reactions involve organic compounds.

You are only one example of the many living organisms on this planet. You are very different from an insect, bird, fish, or flower. Yet all living things on Earth, past and present, share one thing in common. The organic chemistry which makes living things possible is based on the unique properties of carbon.

In this module you will study the vast diversity of organic carbon compounds through their names and classification. You should also become more aware of society's dependence on organic chemistry.



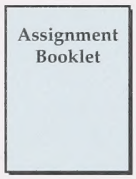
Evaluation

The document you are presently reading is called a Student Module Booklet. It will show you, step by step, what to do and how to do it.

This module, Organic Compounds, has three sections. Within each section, your work is grouped into activities. Within the activities, there are readings and questions for you to answer. By comleting these questions you will construct your own learning, discover scientific connections, and apply what you have learned. The suggested answers in the Appendix of this Student Module Booklet will provide you with immediate feedback on your progress.

In this module, you will be directed to the accompanying Assignment Booklets. You are expected to complete two Assignment Booklets for this module. Your grading in this module is based upon the assignments that you submit for evaluation. The mark distribution is as follows:

Assignment Booklet 6A	
Section 1 Assignment	**40 marks**
Assignment Booklet 6B	
Section 2 Assignment	**25 marks**
Section 3 Assignment	**35 marks**
TOTAL	**100 marks**



When you see this icon, turn to the appropriate Assignment Booklet to find the assignment questions for that section.

SECTION 1

Aliphatics

AOSTRA

What do a nylon jacket, a plastic CD case, and the non-stick coating in your frying pan have in common? Were you aware that these items would not be possible without the oil and gas industry? These items and a vast array of other materials originate in the ground as aliphatic hydrocarbons. Millions of years of development, followed by a short term of processing, turn these hydrocarbons into thousands of products you rely on everyday, such as plastics, Teflon®, and synthetic fabrics.

This section will introduce you to the world of organic chemistry and aliphatic hydrocarbons. You will explore the various types of aliphatic compounds, learning how to name them and how to represent them as structures. You will see how the petroleum industry plays a vital role in providing many of these materials to meet the demands of consumers.

ACTIVITY 1

What Is Organic?

FIGURE 6.1: Variety of Organic Compounds

Which of the items in Figure 6.1 is organic? You probably identified the papers and magazines as organic, which is correct. In fact, most of the items shown, including the plastic wrap on the video disc jacket, the cassette case, and the computer disc cover are made of organic materials.

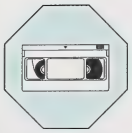
1. What is common to all of the items identified as organic in Figure 6.1?

Check your answers by turning to the Appendix, Section 1: Activity 1.

The intent of the preceding photographic example was to make you realize the enormous variety of materials in the world that are organic-based and contain carbon.

Nelson CHEMISTRY

To learn more about carbon and its compounds, read the introductory section from page 234 to the middle of page 236 in your textbook.



As a further introduction to this activity, view Segment Number 1 Carbon the Compromiser from the video series *Organic Chemistry 1* (TVO/ACCESS Network). This segment will give you a visual introduction to carbon and a brief historical account of organic chemistry.

Now answer the questions that follow.

2. Why are perfumes, some explosives, dyes, grease, oil, and gasoline considered to be organic?

3. Since carbon is located in Group 14 or IVA of the periodic table, what are two characteristics that carbon has?

4. What other nonmetal elements would be expected to have properties similar to carbon?

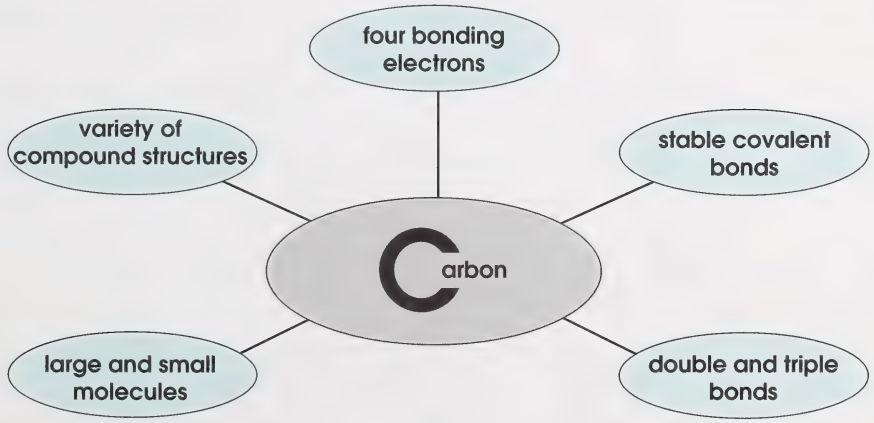
5. What type of bonding do organic compounds contain?

6. Which groups of ionic compounds containing carbon are not considered organic? Why?

7. Which molecular compounds containing carbon are not considered organic?

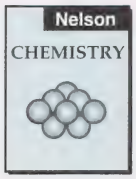
8. What unique bonding properties of carbon makes it ideal for forming so many organic compounds?

Check your answers by turning to the Appendix, Section 1: Activity 1.



models – representations in three dimensions of physical objects or things

The complex nature and variety of carbon compounds often makes it necessary to use **models** to understand these structures. There are a number of ways that you can represent organic molecules on paper and in model form. Each way is suited to highlight different important aspects of structure and function.



The section entitled Structural Models and Diagrams on pages 236 and 237 in your textbook outlines several methods of illustrating carbon compounds. Read these pages to gain an understanding of structure and **isomers**.

In Module 5 you learned how to draw Lewis models (electron dot diagrams) and **structural diagrams** for molecular compounds. This module makes use of that same knowledge, except that the structures are larger.

isomers – compounds with the same molecular formula but different structural formulas

structural diagrams – spatial representations showing the type, number, and arrangement of atoms in molecules

9. Draw a Lewis model and structural formula for ethanol, C_2H_5OH.

10. Reproduce the following two columns. Identify the **expanded molecular formulas** by circling them. Match each expanded molecular formula with its **molecular formula** using connecting lines.

C_3H_8	C_4H_{10}
$CH_3CH_2CH_2CH_3$	$CH_3CH_2CH_2CH_2CH_2CH_3$
$(CH_3)_2CHCH_2CH_3$	$CH_3CH_2CH_3$
C_6H_{14}	C_5H_{12}

expanded molecular formulas – chemical formulas that illustrate the type, number, and groupings of atoms in molecules

molecular formula – a chemical formula that indicates the type and number of atoms in a molecule

11. a. What are isomers?

    b. Draw the three structural isomers of C_5H_{12}, using condensed structural diagrams. Use the information from Figure 9.2 on page 236 of *Nelson Chemistry* to help you. (Draw what you see).

12. What are two types of models that scientists can use to communicate structure? What is the special purpose of each type?

13. What is the difference between a complete structural diagram, a condensed structural diagram, and a line structural diagram?

Check your answers by turning to the Appendix, Section 1: Activity 1.

Since the three-dimensional structure of many carbon compounds is hard to visualize from two-dimensional paper drawings, you will find it much easier to see structures by building models.

Nelson CHEMISTRY

To gain practice and knowledge in molecular model-building, read and perform the investigation described on page 238 of your textbook.

Investigation 9.1: Models of Organic Compounds

Carefully follow the directions of this investigation. Pay special attention to the required components, safety aspects, and applied science skills.

Science Skills

- ☐ A. Initiating
- ☑ B. Collecting
- ☑ C. Organizing
- ☑ D. Analysing
- ☐ E. Synthesizing
- ☐ F. Evaluating

Notes on Model Construction – Your model kit has an instruction booklet which gives directions on the following:

- which colours represent which atoms
- which bonds (wooden sticks) to use when making different types of bonds
- several exercises for practice in building models

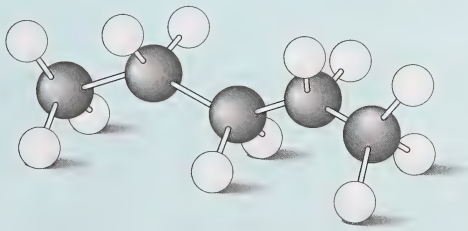
14. Follow the procedural steps as given in your textbook on page 238 and record diagrams for each isomer as requested. Make separate tables to accommodate the structures of each of the molecular formulas given.

Check your answers by turning to the Appendix, Section 1: Activity 1.

You have probably realized from the preceding investigation that the structural diagrams you drew were somewhat simplified from what your models illustrated.

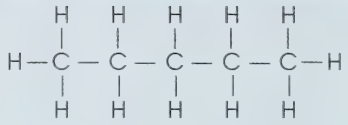
Example

The model of C_5H_{12} in a straight chain looks like the given diagram.



In three dimensions, the bond angles show very clearly.

However, your complete structural diagram of C_5H_{12} would be drawn as shown:



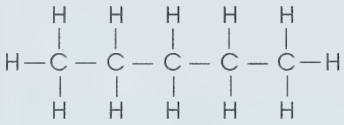
The three dimensional nature of the molecule is not shown – the carbon-carbon bonds are drawn in a straight line.

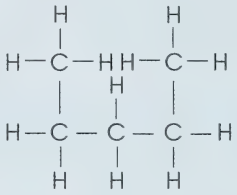
The structural diagrams will be drawn in this straight line fashion (except for branches) throughout Modules 6 and 7.

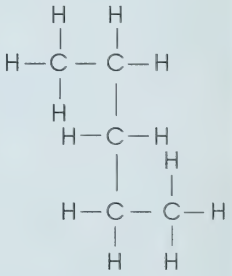
Another important aspect of working with models and structural diagrams is the interpretation of what you see.

Example

The compound C_5H_{12} can be drawn a number of different ways without changing the particular structure.





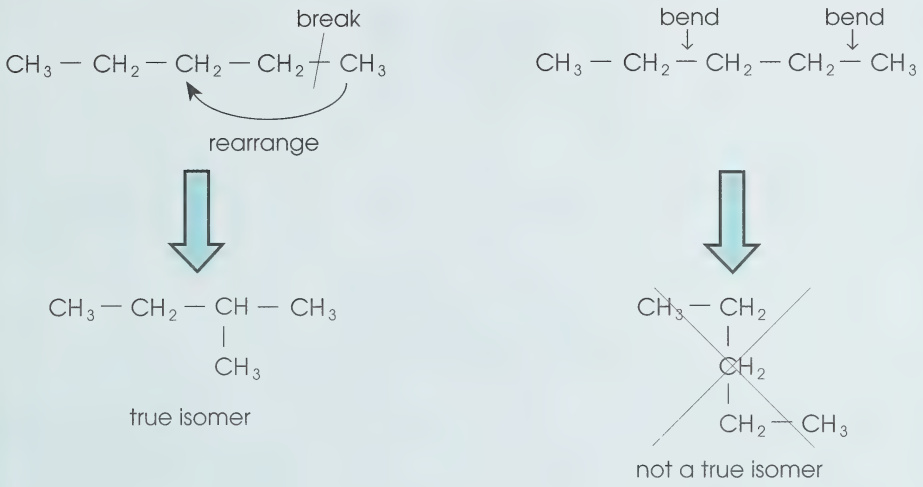


Even though these structures may look different,

they are still the same compound.

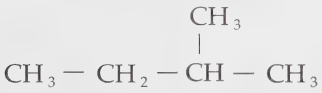
The preceding example has a number of implications for constructing or drawing isomers. The three different structures drawn were **not** different isomers, they were simply bent versions of the same structure. In order to create true isomers, you must break at least one carbon-carbon bond and rearrange the structure.

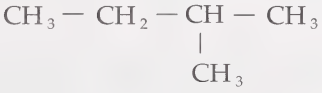
Example

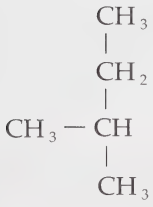


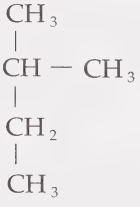
These condensed structural diagrams often work better in representing structures.

Are the following structures the same?





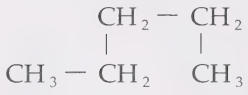


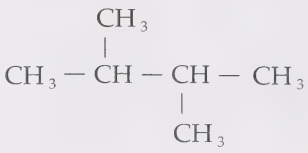


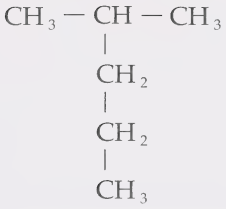
Yes, these are the same structure and compound. The point is, if you take your models and turn them around in your hands, they may look different. But you haven't changed the structure – you have just looked at it from a different angle. This will become important in the next activity when you attempt to name compounds and isomers from their structural diagrams.

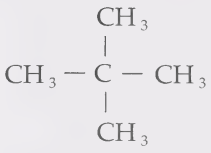
15. Identify which of the following structural diagrams are true isomers of C_6H_{14}, given the following structural diagram as one isomer:

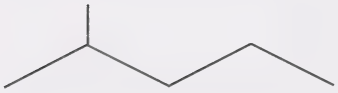
$$CH_3 - CH_2 - CH_2 - CH_2 - CH_2 - CH_3$$

a.


d.


b.


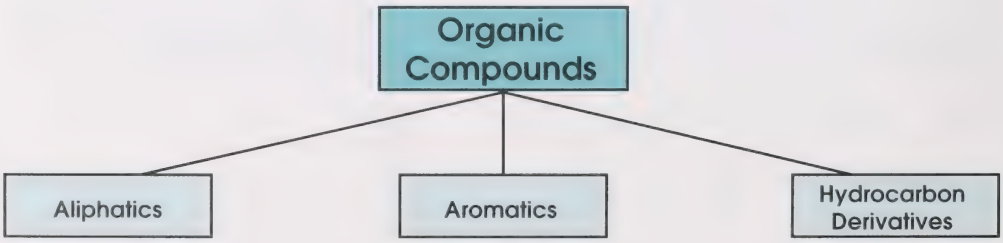
e.


c.


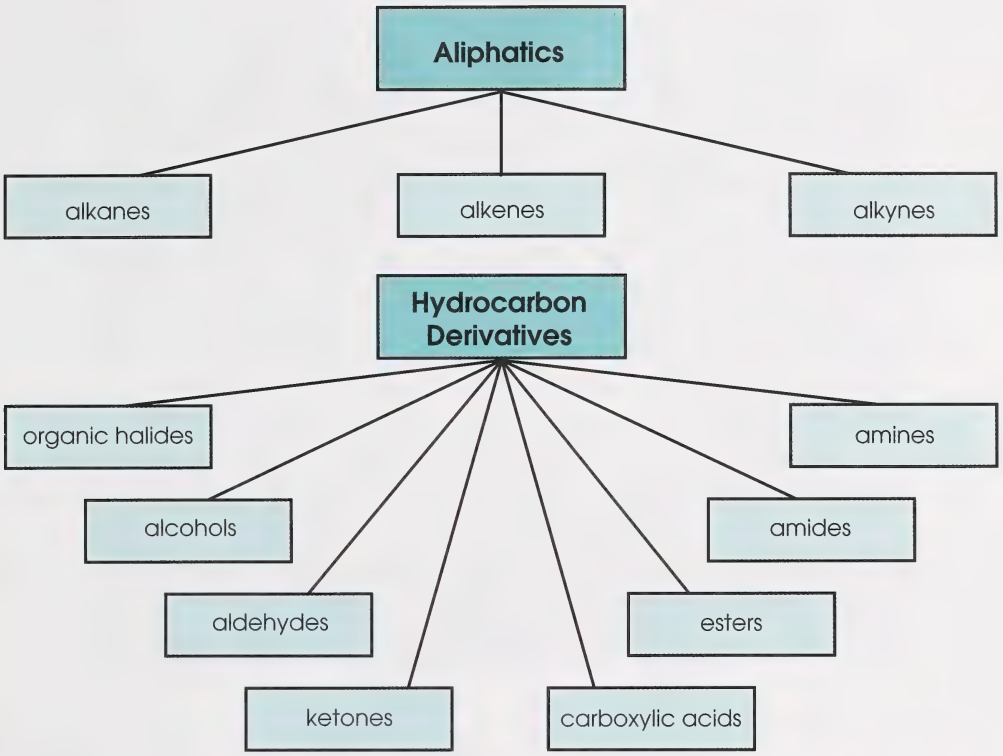
Check your answers by turning to the Appendix, Section 1: Activity 1.

In this activity, you have seen the potential for an enormous variety of organic compounds. You will be introduced to some of the many carbon-based substances in the upcoming activities.

The great number of organic substances creates a need for a way of organizing these compounds into various categories. The following chart illustrates the organization used in this course. Aliphatics are discussed in Section 1, aromatics in Section 2, and hydrocarbon derivatives in Section 3.



The aliphatics and hydrocarbon derivatives categories can be further broken down as follows.



Nelson CHEMISTRY

Organic compounds are classified into the categories you have seen based on their functional group. Families of organic compounds are discussed on pages 238 and 240 (including Table 9.1) of your textbook. Read this section to gain a better idea of how the various functional groups are associated with the different families of compounds.

16. In studying Table 9.1 on page 240, what distinguishes the general formulas of the various compounds?

17. In the general formula of some compounds, what does the *R* represent?

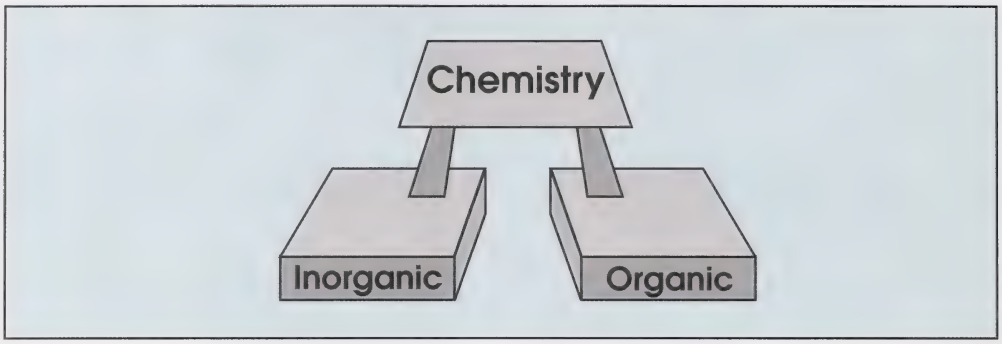
18. Construct a table to include the following information:

    - List the other elements involved in functional groups besides C and H.
    - Indicate the bonding capacity of each of the elements identified.

functional group – a specific atom or group of atoms within a compound that gives the compound its characteristic properties

Check your answers by turning to the Appendix, Section 1: Activity 1.

If the type of chemistry you are studying in this module is considered organic, what type of chemistry have you looked at in previous modules?



You were introduced to the inorganic and organic categories of chemistry at the start of this activity. How do these different areas of chemistry compare? Could you identify household substances in both categories?

19. Make two lists from the following collection of household materials. One list should be titled Inorganic Materials; the other list should be titled Organic Materials.

- vinegar
- baking soda
- pesticide
- ammonia
- drain cleaner
- lighter fluid
- perfume
- rubbing alcohol
- table salt
- ASA tablets
- cooking oil
- bar of soap
- water
- 16-20-0 fertilizer

Check your answers by turning to the Appendix, Section 1: Activity 1.

Organic materials are all around you. You will become more aware of the variety and scope of these materials as you work through the remainder of this module.

ACTIVITY

2 Alkanes

WESTFILE INC.

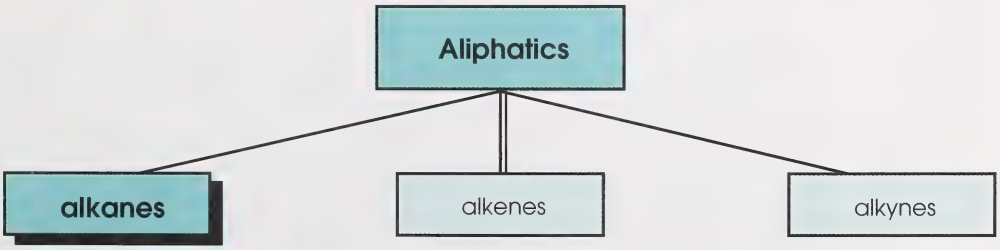
Have you used methane, propane, or butane fuels recently? Did you ever use a propane barbecue or a butane lighter?

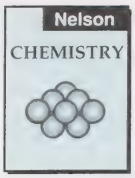
These fuels are examples of the simplest class of organic compounds called *alkanes*. They belong to a class of aliphatic compounds called hydrocarbons. Alkanes are hydrocarbons with only single bonds between carbon atoms, which classifies them as saturated organic compounds.

aliphatic – nonaromatic hydrocarbons

hydrocarbons – any molecules containing only hydrogen and carbon atoms

saturated – organic compounds containing only single carbon-carbon bonds and the maximum number of bonded atoms





Alkanes are obtained from the distillation of petroleum or crude oil in an oil refinery. The refining processes and resultant products are described on pages 24 to 243 in your textbook. Read these pages to learn of the tremendous variety of petroleum products available.

1. What does the number and variety of different substances listed in Table 9.2 suggest about the composition of crude oil or petroleum?

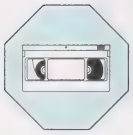
2. What property of the crude oil components enables them to be separated from each other in a refinery?

3. Which petroleum fractions are used for heating purposes?

4. What properties of asphalt make it an ideal roofing or road paving material?

5. What properties of petroleum ether make it an ideal material for cleaning fabrics?

Check your answers by turning to the Appendix, Section 1: Activity 2.



To gain a greater insight into the petroleum industry, view Segment Number 4 Fixing Fuels from the video series *Organic Chemistry 1* (TVO/ACCESS Network). This segment describes the petroleum refining processes and gives a visual explanation of processes such as cracking and reforming.

Can you tell when you look at two brothers or two sisters that they are in fact twins? Their many common characteristics usually give them away. You can often recognize complete families this way as well.

homologous series – a series of compounds with similar functional groups that differ from each other in a systematic, regular fashion

Alkane compounds are similar to each other and are members of the same family or homologous series of compounds. An alkane can be represented by the general formula C_nH_{2n+2}. Each successive member of the alkane homologous series differs from each other by one $-CH_2-$ group.

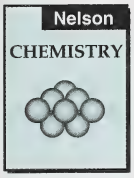
Example

$CH_3-CH_3 + -CH_2- \longrightarrow CH_3-CH_2-CH_3$
ethane propane

$CH_3-CH_2-CH_3 + -CH_2- \longrightarrow CH_3-CH_2-CH_2-CH_3$
propane butane

The first (simplest) member of the alkane series is methane, CH_4.

Other homologous hydrocarbons will be considered in Activity 3. These include the *alkenes*, which contain at least one double bond between carbon atoms, and *alkynes*, which contain at least one triple bond between carbon atoms.



You have already seen that hydrocarbons and other organic compounds can be very complex. Therefore, a systematic way of identifying these substances is required. Read the first two paragraphs (including Table 9.3) of Alkanes on pages 244 and 245 as an introduction to alkanes and their structures.

6. Table 9.3 on page 244 describes the IUPAC name of ten straight-chain alkanes. The abbreviation *IUPAC* stands for International Union of Pure and Applied Chemistry. Why do you think it is important for an international body to decide things such as naming rules for organic compounds?

7. Create a table that illustrates the ten prefixes for the alkanes listed in Table 9.3. Identify the number of carbon atoms each prefix represents in the chain.

8. a. What is a branch, in terms of a hydrocarbon structure?

   b. How are the names of branches distinguished from the main (parent) chain name?

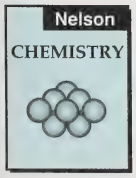
   c. What do all alkane compound names have in common?

9. Write the formulas for the alkanes containing the following number of carbon atoms:

   a. 11 b. 26 c. 30 d. 54

Check your answers by turning to the Appendix, Section 1: Activity 2.

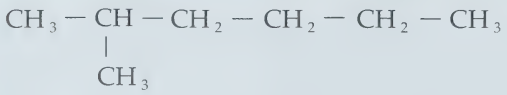
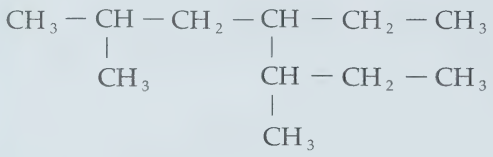
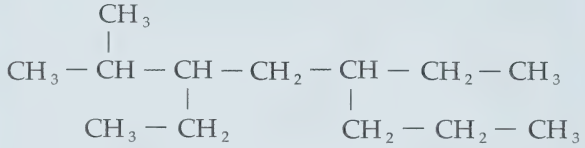
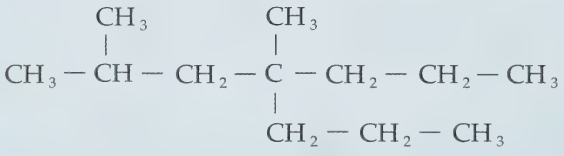
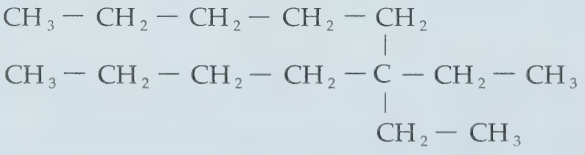
As you have already noticed, the naming system for organic compounds has a number of different rules from the naming rules for inorganic chemicals. These rules must be learned in order for you to be successful in identifying structures of organic compounds. At the same time, it is important to learn the proper methods of drawing structural formulas.



To understand how to name alkane compounds, read page 245 and page 246 up to and including the example given.

10. How do you know from which end to number the parent chain?

11. Reproduce the following chart. Draw a line through the longest continuous chain of carbon atoms in each molecule and name the parent chain.

Structural Diagram	Name of Parent Chain
	
	
	
	
	

Check your answers by turning to the Appendix, Section 1: Activity 2.

There are several other important points you need to know in naming compounds. They will be illustrated with examples as follows:

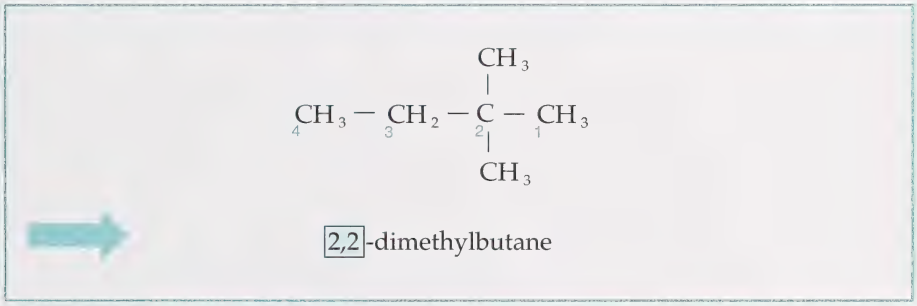
- Both words and numbers are used in organic compound names.

numbers ← Numbers indicate to which carbon atom of the parent chain the branches or alkyl groups are attached. Every branch has to have a number.

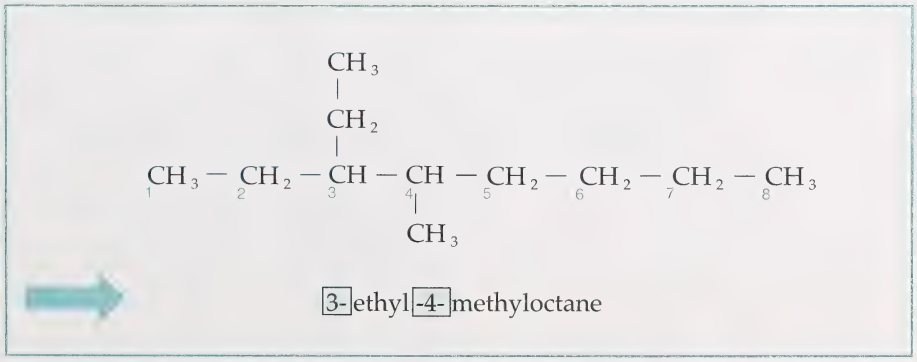
alkyl groups – hydrocarbon chains of the formula C_nH_{2n+1} that act as branches

words ← Prefixes in the words of the name indicate how many carbons are contained in the branches (*-yl* ending) and the main chain (*-ane* ending).

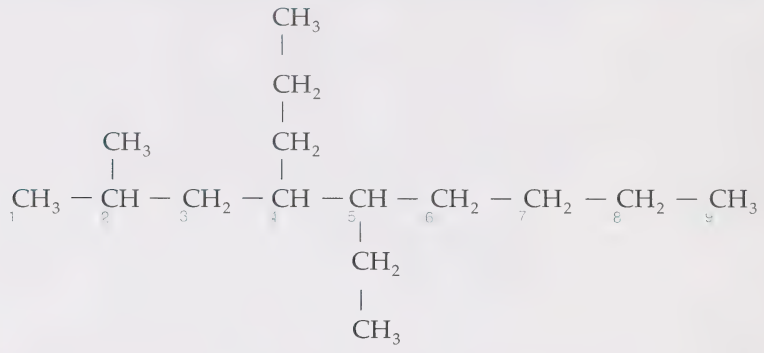
- The proper sequence of numbers and words is as follows:
  - numbers always come **before** the name of the branch or chain to show their location
  - numbers are separated from other numbers by commas



  - numbers are separated from words by hyphens



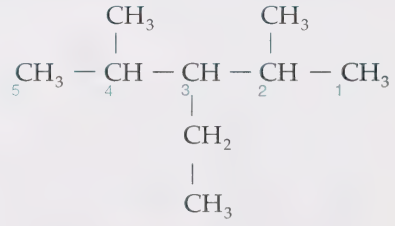
- Branches are ordered (with their numbers) **alphabetically** in the name. (At one time, the branches could be ordered by complexity, but this method is no longer used).



5-[e]thyl-2-[m]ethyl-4-[p]ropylnonane

e before *m* before *p*

- If there is more than one branch of the same type, a locating number is given to **each** branch **and** a prefix indicating the number of that type of branch is attached to the name. This numbering prefix does **not** affect the alphabetical order of the branches.



3-ethyl-[2,4-di][m]ethylpentane

↑ ↑ ↑

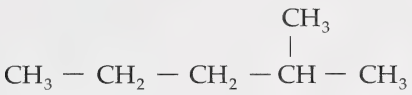
both numbers and prefixes required

still determines alphabetical order: *e* before *m* (ethyl) (methyl)

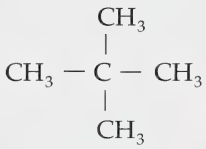
12. Name the following compounds.

Bonus Activity: You may wish to recreate the chains with your molecular models kit.

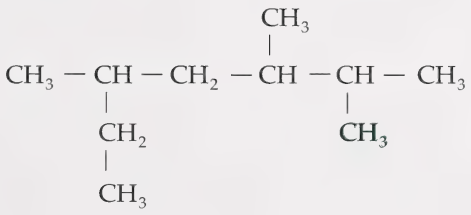
a.



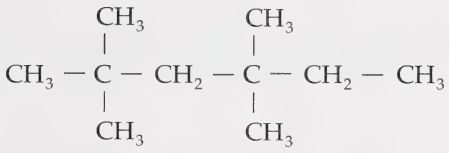
b.



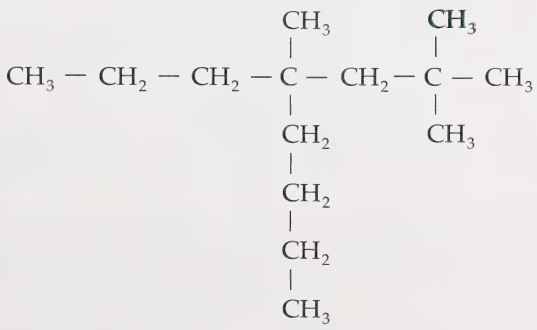
c.



d.

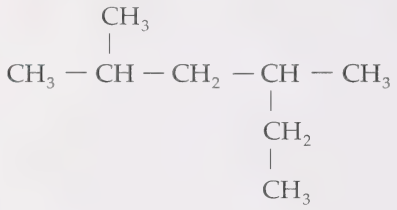


e.



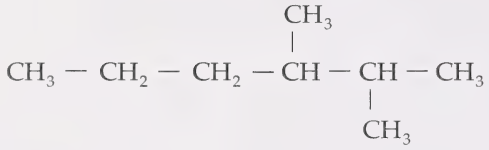
13. For each of the following structures and/or names, describe what is wrong and correct the mistake(s).

a.



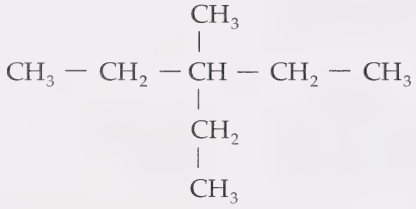
4-ethyl-2-methylpentane

b.



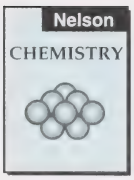
4,5-methylhexane

c.



3-methyl-3-ethylpentane

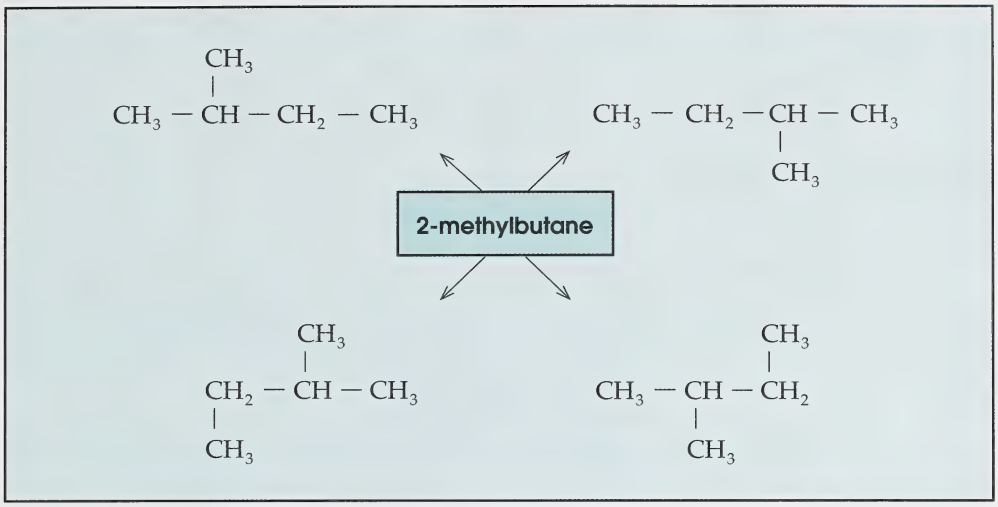
Check your answers by turning to the Appendix, Section 1: Activity 2.



You will often be called upon to show what an organic compound will look like structurally, given its name. When drawing structural diagrams for molecules, you must follow a few simple rules. Read the bottom of page 246 and all of page 247 in your textbook and study the examples given.

There are a few points to note when drawing structural diagrams.

- The parent chain should be drawn straight to avoid mistakes. Do not put bends in the chain.
- The same structure can be drawn several ways and still be correct. Check to see that the branches are attached to the correct carbons and that the parent chain is the right length.



14. Draw structural diagrams for the following compounds:

    a. 3-ethyl-3,4-dimethylhexane

    b. 2,2,4-trimethylpentane

    c. 5-ethyl-3,3-dimethylheptane

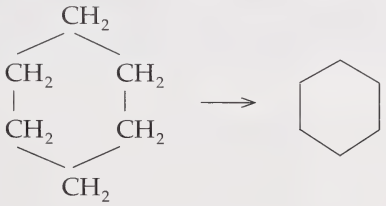
    d. 6-ethyl-2,5-dimethyl-4-propylnonane

Check your answers by turning to the Appendix, Section 1: Activity 2.

Nelson CHEMISTRY

The alkanes that you have studied so far are known as *acyclic* alkanes because they form open chain molecules. When the alkanes assume a polygon-shaped molecule or a closed ring they are known as *cycloalkanes,* as shown on page 247 of your textbook.

When drawing line structural diagrams of cycloalkanes, the correct number of hydrogens are assumed to be on each carbon as before.



cyclohexane

15. Write the molecular formula for cyclohexane. How is it different from the straight chain compound hexane? Why?

16. Draw line structural diagrams for the following:

    a. cyclopentane

    b. cyclooctane

17. What familiar traffic device is the shape of cyclooctane used for in society?

Check your answers by turning to the Appendix, Section 1: Activity 2.

You have been provided with the basic rules for naming and drawing alkanes. Many of these basic rules apply to the other types of compounds.

ACTIVITY 3

Alkenes and Alkynes

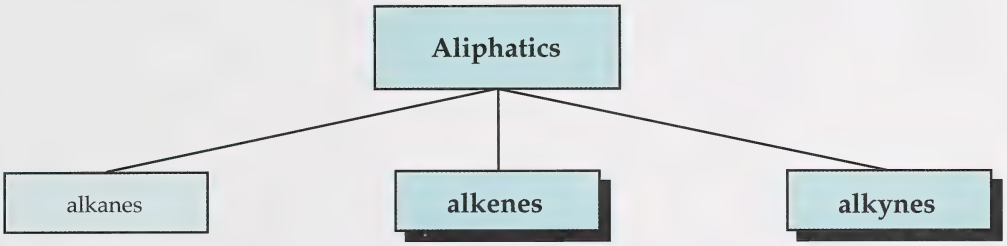
PHOTO SEARCH LTD.

Do you have a healthy, balanced diet? Many food products, to meet the more health-conscious needs of today's society, emphasize their use of polyunsaturated materials. Do you know what this means?

When was the last time you used something plastic? Is the pen or pencil you are using right now plastic? Society relies heavily on plastics and variations of plastics.

polyunsaturates – long chain hydrocarbons with many multiple carbon bonds

Both plastics and **polyunsaturates** come from compounds classified as alkenes or alkynes. These types of substances have become an integral part of your daily life.



Nelson CHEMISTRY

As an introduction to alkenes and alkynes, read the information on pages 248 and 249 of your textbook. Don't forget the margin information.

1. a. Both the alkenes and alkynes are described as families of compounds in your textbook. What term was used that was similar to describing alkanes as a family? Could this term fit each of the alkene and alkyne families? Explain.

   b. What are the first members of the alkene and alkyne families? How do they differ from alkanes?

2. How can you tell, from the compound name, whether you have a double- or triple-bond compound?

3. What is common to all alkane, alkene, and alkyne names?

4. What diagnostic test can be used to distinguish an alkane from an alkene?

Check your answers by turning to the Appendix, Section 1: Activity 3.

Alkenes and alkynes are similar to alkanes in that they also have general formulas.

If you have trouble understanding the development of the general formulas, remember that each bond involves two bonding electrons, so each multiple bond formed requires the loss of two hydrogen atoms. Examine Figure 6.2.

The presence of multiple bonds in alkenes and alkynes makes them **unsaturated** and much more reactive, as you will discover in Module 7.

unsaturated – compounds containing multiple carbon-carbon bonds

5. Write the molecular formula for the alkenes containing the following number of carbon atoms:

   a. seven
   b. twelve
   c. eight
   d. fourteen

6. Write the molecular formula for the alkynes containing the following number of carbon atoms:

   a. five
   b. eleven
   c. nine
   d. fifteen

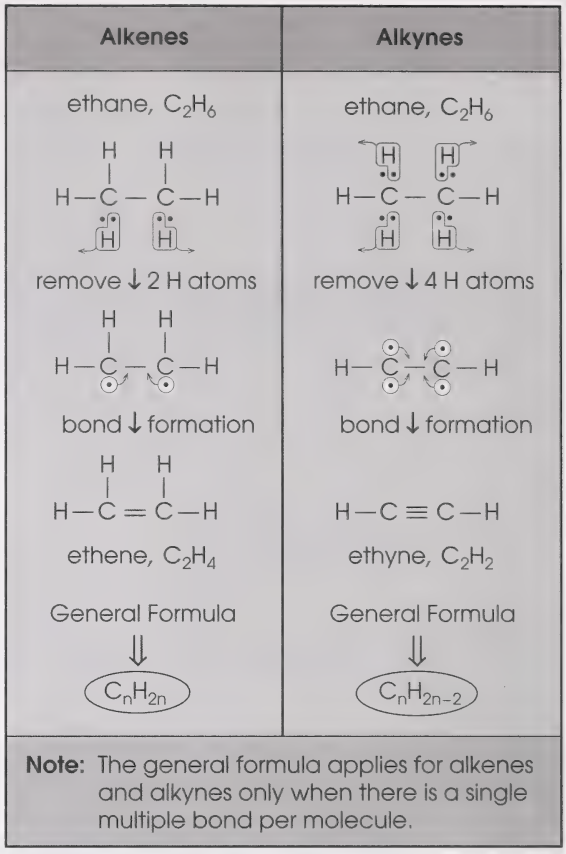


FIGURE 6.2: General Formulas for Alkenes and Alkynes

Should you be able to draw structural isomers for alkenes and alkynes the way you did for alkanes? How would the structures of the isomers compare?

When dealing with alkanes, you found that moving pieces of carbon chains (branches) around created different isomers. With alkenes and alkynes, though, isomers can be created by moving the branches, the multiple bond, or both.

Example

There are two possible isomers for the alkane with the molecular formula C_4H_{10}.

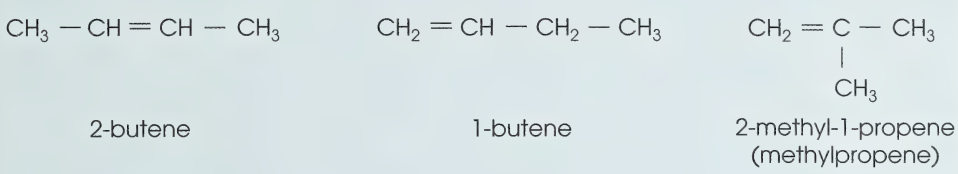
$CH_3 - CH_2 - CH_2 - CH_3$

butane

$CH_3 - CH(CH_3) - CH_3$

2-methylpropane (methylpropane)

However, there are three possible isomers for the alkene with the molecular formula C_4H_8:



2-butene | 1-butene | 2-methyl-1-propene (methylpropene)

Both branches and the double bond were moved to create the isomers.

7. Why are $CH_2 = CH - CH_2 - CH_3$ and $CH_3 - CH_2 - CH = CH_2$ not isomers of each other?

8. Draw all the noncyclic structural isomers of C_5H_{10} and C_5H_8. (**Hint:** Identify each molecular formula first as an alkane, alkene, or alkyne using the general formulas).

Check your answers by turning to the Appendix, Section 1: Activity 3.

Nelson CHEMISTRY

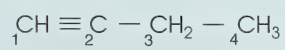
Read the section Naming Alkenes and Alkynes on page 250 in *Nelson Chemistry*. You will notice that all the naming rules you used for alkanes have been kept, with the exception of two changes. Take note of the similarities and differences in naming.

One additional point to the naming rules given in your textbook is worth considering:

- When the double or triple bond is located by a number in the name, that number must be the lowest possible, just like when you number branches.

Example

In the following alkyne,

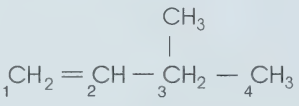


the triple bond is between carbons 1 and 2. Since 1 is lower than 2, the triple bond is located by using the 1. Therefore the name of the compound is 1-butyne.

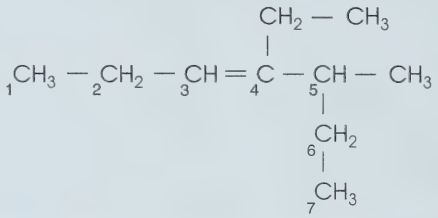
Some additional examples of alkenes and alkynes are shown as follows.

Examples

Alkene Nomenclature

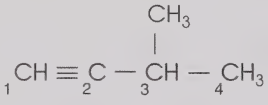


3-methyl-1-butene

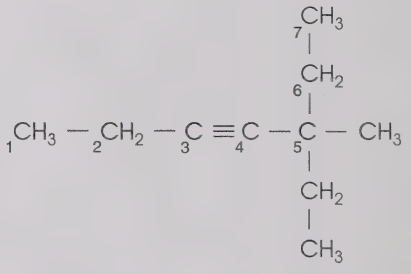


4-ethyl-5-methyl-3-heptene

Alkyne Nomenclature



3-methyl-1-butyne



5-ethyl-5-methyl-3-heptyne

9. When alkenes or alkynes are named, how is the chain numbered?

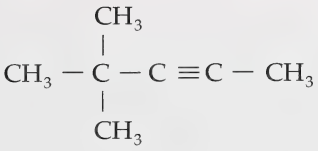
10. How is the position of the multiple bond indicated in the molecule name?

11. Name the following alkenes and alkynes.

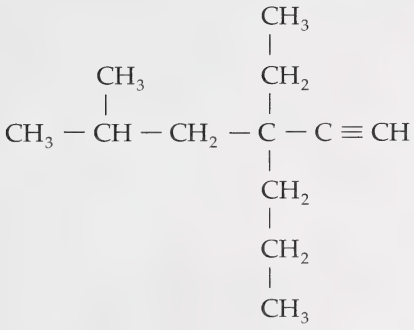
    a. $CH_3 - CH_2 - CH = CH - CH_2 - CH_3$

    b. $CH_3 - CH_2 - CH_2 - CH_2 - C(CH_2 - CH_2 - CH_3) = CH - CH_3$

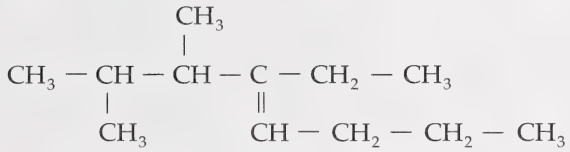
c.



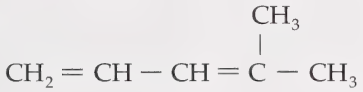
d.



e.



f. Optional:



12. Draw condensed structural diagrams for the following alkenes and alkynes.

a. 2-methyl-1-butene

b. 4,5-dimethyl-2-hexyne

c. 5-ethyl-3,4,6-trimethyl-2-octene

d. 3-ethyl-4-methyl-1-pentyne

Check your answers by turning to the Appendix, Section 1: Activity 3.

Nelson CHEMISTRY

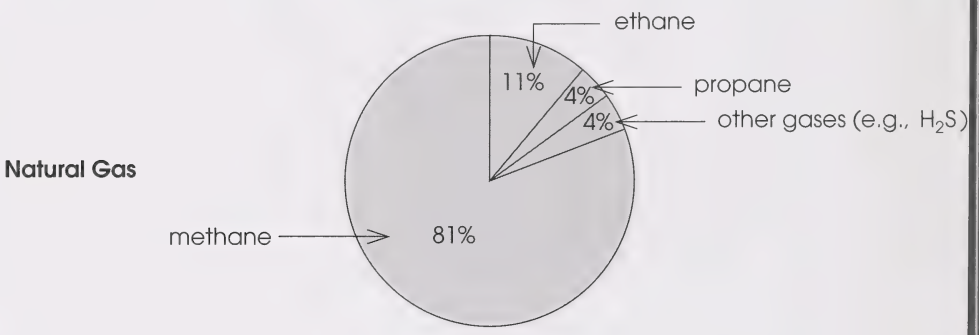
Like the alkanes, alkenes can form cyclic compounds called cycloalkenes. Two good examples of cycloalkenes, cortisone and cholesterol, are shown on page 250 of your textbook in the margin.

DID YOU KNOW?

Alkenes also form compounds called *dienes* which contain two carbon-carbon double bonds. For example, the compound $CH_2 = CH - CH = CH_2$, known as 1, 3-butadiene, is used to make synthetic rubber. Synthetic rubber has largely replaced natural rubber by improving its properties and alleviating its decreasing supply sources.

Although the uses and applications for alkenes and alkynes are enormous, a few common uses deserve your attention.

Natural gas is a mixture of several hydrocarbons. Typically it contains about 81% methane, 11% ethane, and 4% propane.



The ethane is extracted from natural gas and converted into ethene (ethylene). In Alberta, petrochemical industries use ethene to make such products as polyethene (polyethylene) plastic, polyvinyl chloride, and ethylene glycol (radiator antifreeze). Similarly, propane is converted into propene (propylene) used to make polypropene (polypropylene). It could end up as your water skiing tow rope or your living-room rug fibre. These types of compounds will be explored in greater depth in Module 7.

Ethyne (acetylene) reacts with oxygen in the familiar oxyacetylene reaction to produce the highest temperatures possible by chemical means. It is used for welding and the cutting of metals.

DID YOU KNOW?

At the turn of the century before bonding was fully understood, ethyne, C_2H_2, was originally given the name acetylene. Even though its common or trivial name suggests a double bond compound, the molecule contains a triple bond. Because of its wide and common usage in oxyacetylene welding, the older name is still often used.

13. Why is natural gas such an important nonrenewable resource?

Although unsaturated hydrocarbons are produced indirectly from saturated alkanes, their industrial applications are numerous because of their high reactivity and isomerism. You will be examining two unsaturated isomers for structure and physical properties in the next investigation.

Investigation 9.3: Structures and Properties of Isomers

Nelson CHEMISTRY

Carefully follow the directions given for the investigation on page 251 of your textbook. Pay special attention to the required components, safety aspects, and appropriate science skills.

Guidelines

Science Skills

- ☐ A. Initiating
- ☑ B. Collecting
- ☑ C. Organizing
- ☑ D. Analysing
- ☑ E. Synthesizing
- ☐ F. Evaluating

- Use all materials as suggested on page 251 of your textbook.
- Use the springs in the model kit to make your double bonds and any cyclic isomers.
- If you do not have access to a reference source as mentioned in your textbook, obtain the necessary melting and boiling points from the answer to the following question in the Appendix of this module.
- Complete the evidence for the investigation by recording your observations in the table as directed in the following two questions.

14. Draw the structural diagrams of the given models and their isomers. Write the IUPAC name for the structures and record the melting and boiling points for each compound. Organize this information in a table with the following headings:

Molecular Formula	Structural Diagram	IUPAC Name	Melting Point (°C)	Boiling Point (°C)

a. C_4H_8 b. C_4H_6

Check your answers by turning to the Appendix, Section 1: Activity 3.

As your analysis, answer the following question. Use your knowledge from Module 5 about intermolecular forces and melting and boiling points in your answer.

15. Look at the four possible noncyclic isomers of C_4H_8 that you constructed. Propose a possible explanation for the differences in their melting and boiling points.

Check your answers by turning to the Appendix, Section 1: Activity 3.

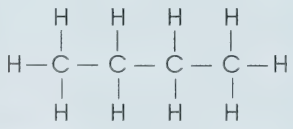
The chemistry of alkenes and alkynes has enormous importance in present day society. Their wide range of applications will become more evident as you work through Module 7.

Follow-up Activities

If you had difficulties understanding the concepts in the activities, it is recommended that you do the Extra Help. If you have a clear understanding of the concepts, it is recommended that you do the Enrichment.

Extra Help

The following table summarizes the various ways in which the formulas of aliphatic hydrocarbons can be written. This review will be used for the questions that follow.

Formula	Formula Type	Comments
C_4H_6 1-butyne	molecular	shows kind and number of all atoms
 2-butyne	Lewis dot	shows bonding capacity of atoms and atom arrangement
 butyne	complete structural	shows kind, number, and arrangement of atoms, as well as all bonds
$CH_3 - CH = CH - CH_3$ 2-butyne	condensed structural	shows carbon bonds only; shows hydrogen atoms but no C — H bonds
 pentane	line structural	shows carbon atoms (points of lines) and some shape – assumes hydrogens

1. Create a table with the following headings:

Molecular Formula and Name	Complete Structure	Condensed Structure

Draw the necessary structures of the following compounds to complete your table. Draw unbranched chains only.

a. C_2H_6 c. C_2H_2 e. C_5H_{12} g. C_5H_{10}

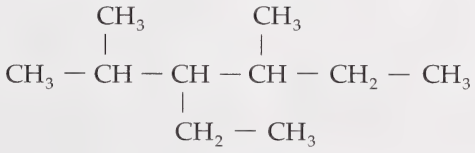
b. C_4H_{10} d. C_5H_8 f. C_3H_4

Nelson CHEMISTRY

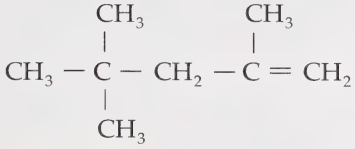
Review the summaries on page 246 for naming alkanes and page 250 for naming alkenes and alkynes before answering the following questions.

2. Name the following molecules.

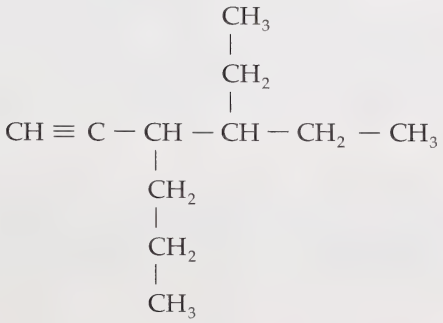
a.



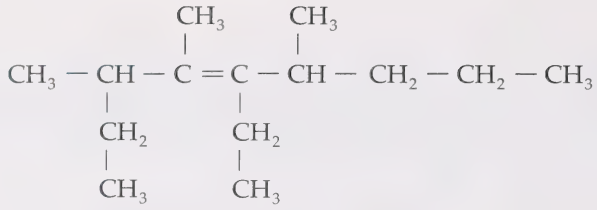
b.



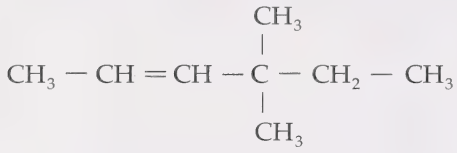
c.



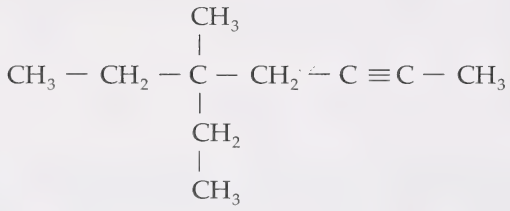
d.

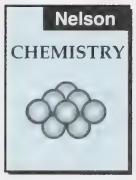


e.



f.





Review the summary on page 247 in your textbook for drawing alkane structures before answering the following questions.

The same rules apply to the drawing of alkenes and alkynes except that a double or triple bond must be included in the parent chain. The carbon atoms are laid out, the multiple bond is properly placed, and the branches are then attached on the parent chain.

3. Draw condensed structural diagrams for the following molecules.

   a. 2,4-dimethyl-3-hexene

   b. 5-ethyl-4-propyl-2-heptyne

   c. 3,3-diethyl-5-methylheptane

   d. 3,5-diethyl-2,4,7,8-tetramethyl-5-propyldecane

   e. 3-methyl-1-butyne

   f. 2,3-dimethyl-2-butene

Check your answers by turning to the Appendix, Section 1: Extra Help.

Enrichment

Do **one** of the following:

1. Most of the natural gas in Alberta contains hydrogen sulphide, H_2S, a poisonous gas with the odour of rotten eggs. Industry refers to natural gas containing H_2S as *sour gas*. Use library research to prepare a short report on the technology developed for removing H_2S from natural gas.

2. The ethene (ethylene) industry in Alberta is significant. Ethene is the base compound for a variety of products. Use library research to prepare a short report on ethene production technology and its applications. An alternate suggestion could be to visit one of the ethylene production plants and talk to a chemist at the plant. Prepare a short report on your findings.

Check your answers by turning to the Appendix, Section 1: Enrichment.

Conclusion

Organic chemistry deals with carbon-based compounds. Carbon bonds covalently to other atoms as well as to other carbon atoms. Hydrocarbon compounds contain only carbon and hydrogen atoms.

Aliphatic organic compounds provide a diverse variety of products and create a substantial economic base for Alberta and other provinces. The homologous series of alkanes, alkenes, and alkynes allow for a wide range of physical and chemical properties. In this section, you have examined the structural characteristics of aliphatics and learned a naming system that will enable you to recognize hydrocarbon compounds as well as lay the foundation for the study of other organic materials.

Assignment Booklet

ASSIGNMENT

Turn to Assignment Booklet 6A and do the assignment for Section 1.

SECTION 2

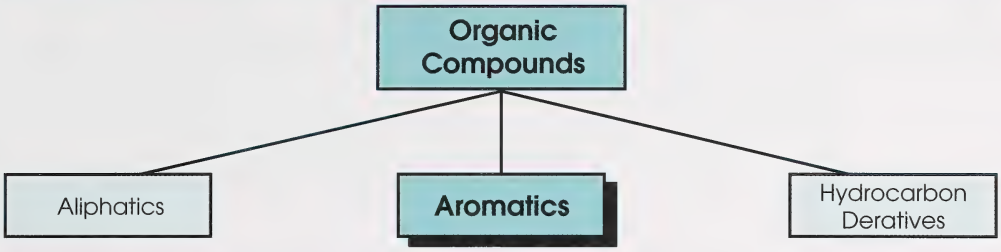
Aromatics

Would you believe that ASA (headache medicine), vanillin, dynamite, some local anaesthetics, and your dyed blue jeans all have something in common? What is this mysterious substance? All of these products contain organic compounds that belong to a family of compounds called aromatics – unsaturated structures with unique characteristics.

Where does the term aromatic come from? What is so special about the benzene ring that all the aromatics contain? This section will examine some of the characteristics of aromatic compounds. You will learn how to name and draw the benzene structures which give aromatics their special properties. As well, you will discover the many uses of aromatics and some of the dangers that are associated with them.

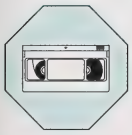
ACTIVITY 1

Identification and Uses

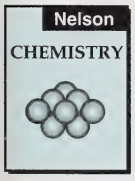


aromatic – an organic compound containing benzene or benzene-like ring structures

What is it about a substance that allows it to be part of a medicine in one case and the main component of an explosive in another case?



Aromatic compounds owe their special properties to a compound called benzene, C_6H_6. As was mentioned in the video segment Carbon the Compromiser referenced in Section 1, a man named Kekulé first envisioned the structure of benzene in the mid 1860s.



The structure of benzene is important in understanding aromatics. Benzene's structure has presented a difficult challenge to chemists. To learn more about aromatics, read the historical account of benzene and aromatics on pages 251 and 252 in your textbook and use the information to answer the questions that follow.

1. Why were so many compounds originally called aromatics?

2. What is an aromatic, if fragrance is no longer considered a significant property of aromatics?

3. What is the molecular formula for benzene?

4. What is the difference between an aliphatic and aromatic hydrocarbon?

When coal is heated in the absence of air, a residue called coke is produced. Coke is needed for the smelting of iron and production of steel. Benzene, C_6H_6, was first obtained in 1825 from the black oily liquid coal tar produced in the process. It is also the source of many other aromatics.

The benzene molecule is a flat ring of six carbon atoms with one hydrogen bonded to each carbon. Figure 6.3 shows two possible ways of representing a benzene molecule as proposed by Kekulé.

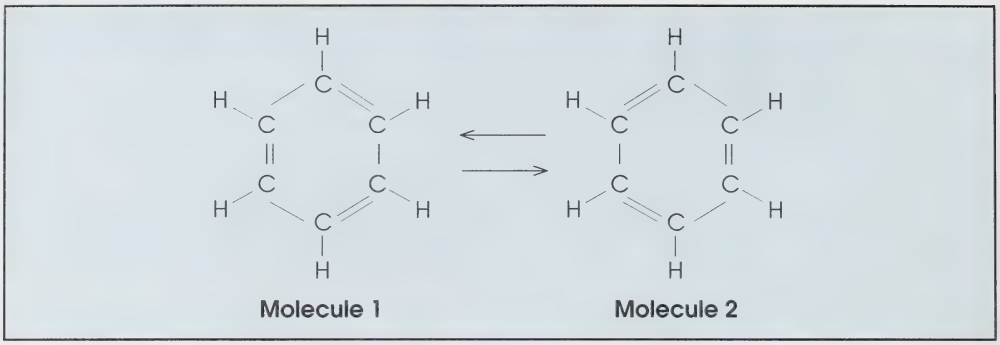


FIGURE 6.3: Kekulé Model of Benzene

5. How does benzene molecule 2 differ from benzene molecule 1 as shown in Figure 6.3?

As your textbook mentions, evidence suggests that the benzene molecule is neither of the two structures shown in Figure 6.3 but an intermediate structure of both as represented by the arrows.

hybrid – a cross or combination of two or more different structures

Since the bonds in benzene are of equal length, the structure of benzene is now considered to be a hybrid, as outlined in Figure 6.4. The carbon atoms are not shown in the model.

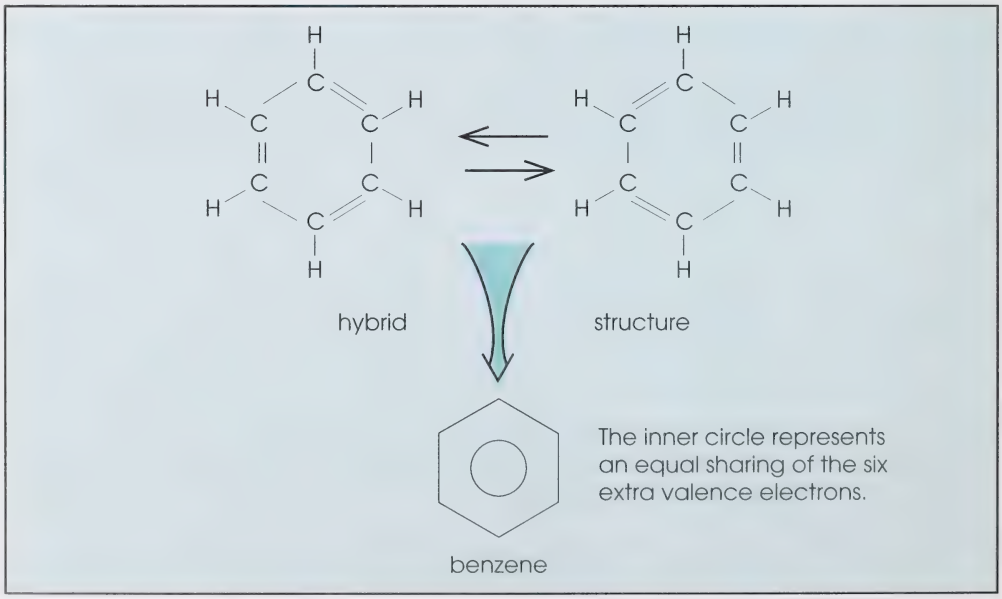


FIGURE 6.4: Hybrid Structure of Benzene

6. Why was the Kekulé model of a benzene molecule incorrect?

7. What does the hybrid structure of a benzene molecule indicate or represent according to Figure 6.4?

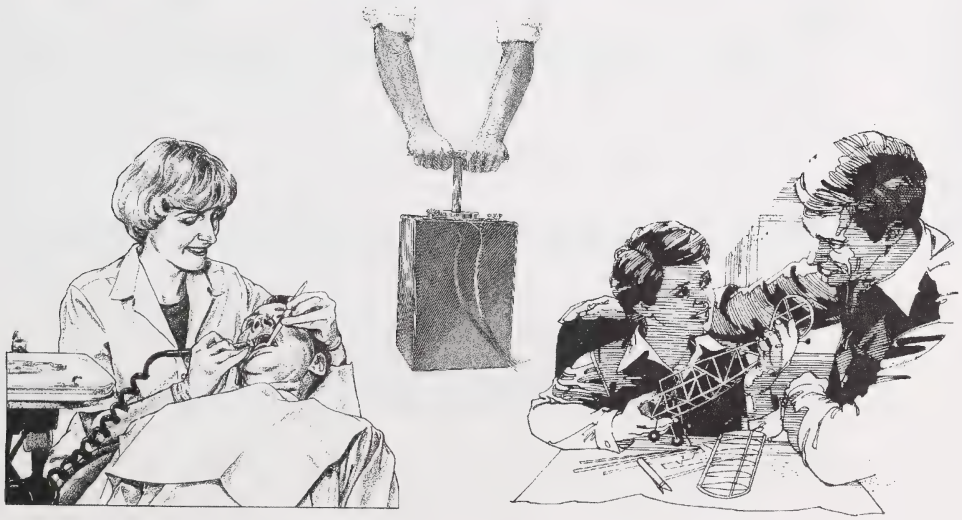
Check your answers by turning to the Appendix, Section 2: Activity 1.

From now on, a benzene molecule will be represented as the following:

You will notice that the structural diagram of the benzene molecule does not show the six carbon atoms or six hydrogen atoms present in the molecule. Each carbon atom still has four bonds: one to the bonded hydrogen atom, one bonded to each adjacent carbon atom, and one shared equally with the whole ring.

DID YOU KNOW?

In some reference books the structural diagram of the benzene molecule may still be written as . This usage is misleading. Measurements show that the length of a double bond is shorter than that of a single bond. The benzene molecule, however, contains bonds equal in length but intermediate in length between double and single bonds.



arene – an aromatic hydrocarbon or a derivative of an aromatic hydrocarbon

Whenever aromatics and aliphatics are both bonded together to form compounds the molecules are known as arenes. Figure 6.5 illustrates benzene and some examples of common arenes. Use the information from the chart to answer the following questions.

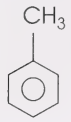
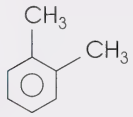
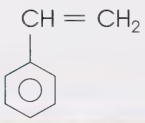
Structural Formula	Name	Comments and Uses
	benzene	• used in production of leather, varnish, linoleum, dyes, plastics, local anaesthetics • solvent for rubber, gums, resins • is a known carcinogen
	toluene (methylbenzene)	• used in production of dyes, explosives, glues • solvent for extraction of plant chemicals
	xylene (1,2-dimethyl-benzene)	• used in production of dyes and xylocaine (a local dental anaesthetic) • starting material for films and bottles
	styrene (ethenylbenzene or vinylbenzene)	• used in production of plastics, polystyrene (Styrofoam), synthetic rubber

FIGURE 6.5: Uses of Benzene Compounds

8. Why are toluene, xylene, and styrene called arenes?

9. Which arene would have the molecular formula, $C_6H_4(CH_3)_2$?

10. Make a list of some potential hazards and benefits of benzene compounds. Organize your response in a table similar to the following:

Benefits	Hazards

You may have heard of some of the more common arenes illustrated in Figure 6.6.

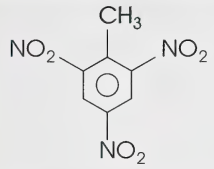
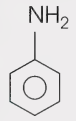
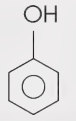
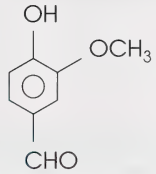
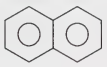
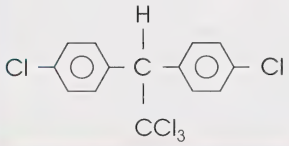
Structural Formula	Name	Comments and Uses
	TNT (2,4,6-trinitrotoluene)	• explosive
	aniline (aminobenzene)	• production of dyes, medicines, perfumes
	phenol (hydroxybenzene)	• disinfectant, germicide (commonly used in hospitals)
	vanillin	• vanilla flavour
	naphthalene	• mothballs
	DDT (dichlorodiphenyltrichoroethane)	• insecticide

FIGURE 6.6: Common Benzene Compounds

11. What is the molecular formula for naphthalene?

12. a. What name is most likely given to the NO_2 groups bonded to TNT?

    b. What name is most likely given to the NH_2 group bonded to aniline?

13. a. In what way are the molecules in Figure 6.6 similar?

    b. In what way are the molecules different?

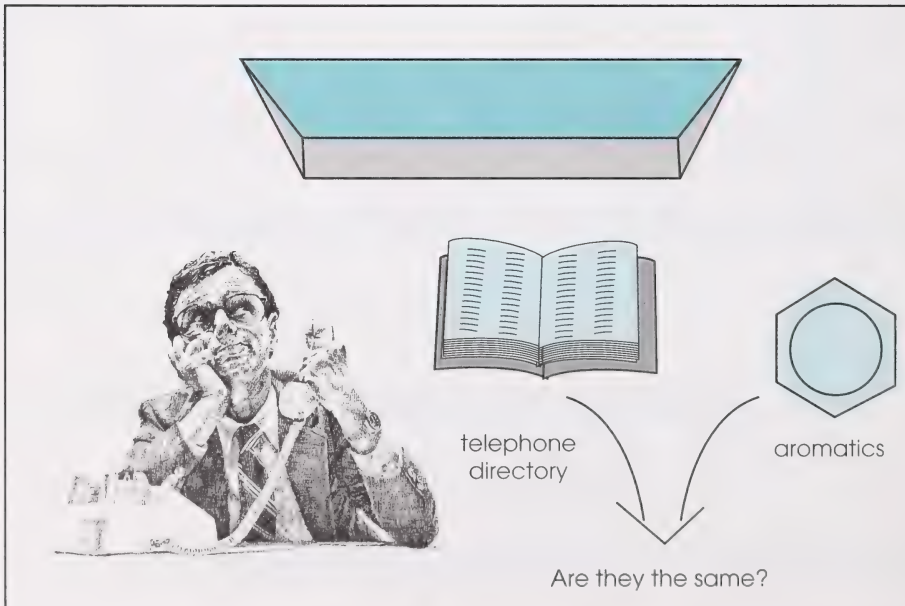
Check your answers by turning to the Appendix, Section 2: Activity 1.

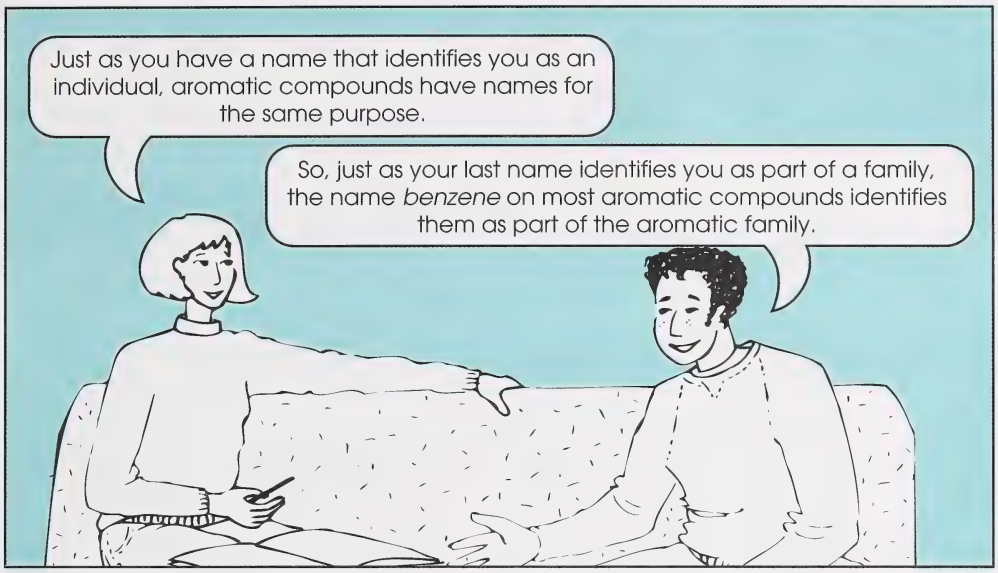
As you have discovered, aromatic compounds comprise a diverse class of organic substances. The broad and complex structures necessitate the need for an organized method of description, just as was needed for aliphatic compounds. The method is discussed in the next activity.

ACTIVITY

2 Naming and Structure

Why do people have names? What rules govern the list of names in a large telephone directory? Would the same rules apply to naming the thousands of different aromatic hydrocarbons?




Just as you have a name that identifies you as an individual, aromatic compounds have names for the same purpose.
So, just as your last name identifies you as part of a family, the name *benzene* on most aromatic compounds identifies them as part of the aromatic family.

Nelson CHEMISTRY

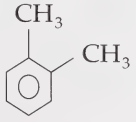
Aromatic compounds have two main ways of being named. To find out about the aromatic naming system, read pages 252 and 253 in your textbook.

1. What name is given to an aromatic in which an alkyl group is bonded to a benzene ring?

2. What does an alkyl group replace in an alkylbenzene molecule?

3. When two hydrogen atoms are replaced by two alkyl groups, how many isomer possibilities are created?

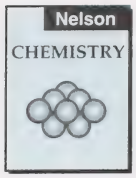
4. Xylene is the common name for one of the arenes that was introduced earlier. Its structure appears as follows:



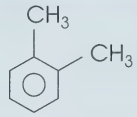
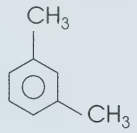
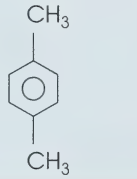
Why would the IUPAC accepted name for xylene be 1,2-dimethylbenzene and not 2,3- or 4,5-dimethylbenzene?

5. Draw and name the two other possible isomers for a molecule containing the benzene ring and two bonded methyl groups.

Check your answers by turning to the Appendix, Section 2: Activity 2.

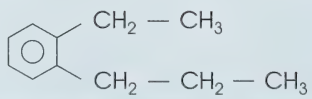


Although IUPAC has developed a logical system for naming aromatic hydrocarbons, another method exists for naming the isomer compounds of benzene. It is a much older method for naming compounds and is referred to as a classical system. For an explanation of this system, review the information given in the margin note on page 253 of your textbook. The naming systems are summarized in the following table.

Molecular Structure	IUPAC Accepted Name	Classical Name
	1,2-dimethylbenzene	o-dimethylbenzene (ortho)
	1,3-dimethylbenzene	m-dimethylbenzene (meta)
	1,4-dimethylbenzene	p-dimethylbenzene (para)

If you have two or more different-sized branches on a benzene ring, you follow the same rules as you used before – list the branches alphabetically. Also, if possible, give the first listed branch the lowest number.

Example



1-ethyl-2-propylbenzene
or
o-ethylpropylbenzene

6. Name the prefix used in naming aromatics when the alkyl groups are characterized by a

   a. 1,2 **disubstitution** pattern or are next to each other

   b. 1,3 disubstitution pattern or are separated by one hydrogen atom

   c. 1,4 disubstitution pattern or are separated by two hydrogen atoms

disubstitution – the substitution of two hydrogen atoms on a benzene ring by two other atoms or groups of atoms

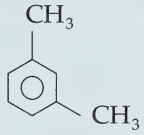
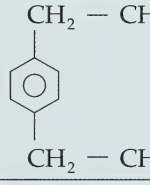
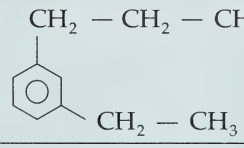
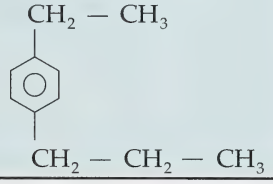
7. Use the IUPAC system to name these aromatics that contain one alkyl group in the molecule.

a.

b.

c.

8. These aromatics contain two alkyl groups in the molecule. Use the IUPAC and classical systems to name the following.

Molecular Structure	IUPAC Name	Classical Name
a. 		
b. 		
c. 		
d. 		

9. Draw the following aromatic hydrocarbons.

a. 1-ethyl-2-methylbenzene

b. 1-ethyl-2,3-dimethylbenzene

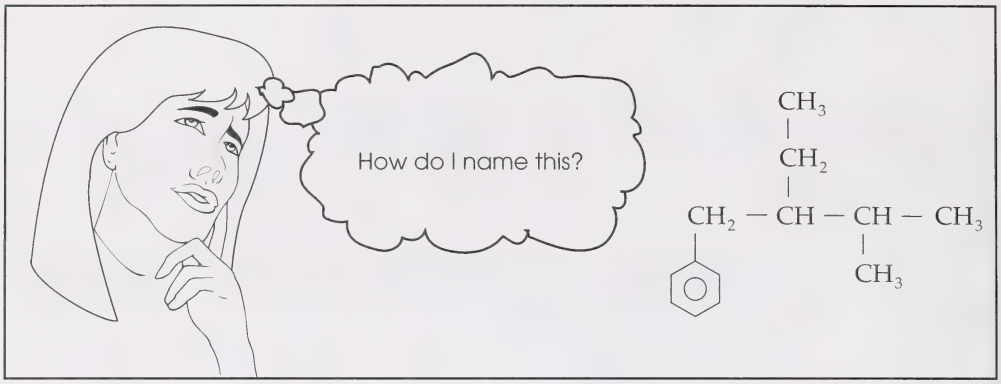
c. 1,3-dimethyl-5-propylbenzene

d. 1-methyl-4-propylbenzene

e. paradimethylbenzene

Check your answers by turning to the Appendix, Section 2: Activity 2.

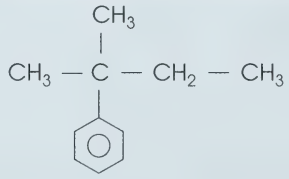
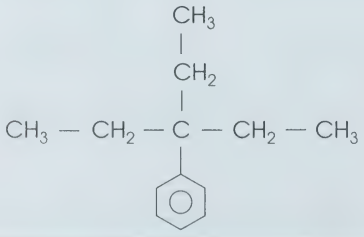
What do you suppose happens when a compound is too large or complicated to be named as a benzene compound? What naming rules do you follow then?



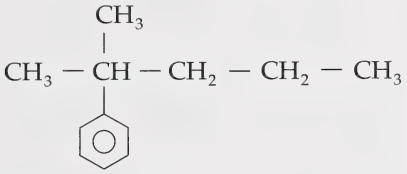
Review the second paragraph on page 253 of your textbook to see how you name aromatic compounds when benzene is considered a branch.

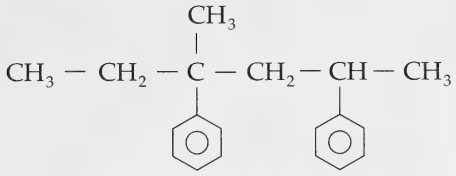
10. What is the benzene ring called when it is considered to be similar to an alkyl branch rather than the parent chain?

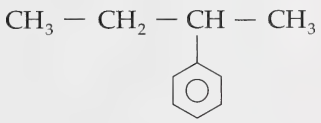
Large-molecule aromatic compounds are named in the same way that aliphatic hydrocarbons are named.

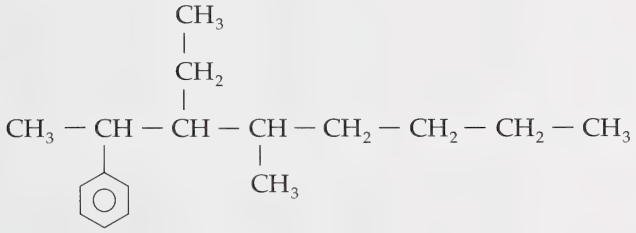
Example	
Molecular Structure	**IUPAC Accepted Name**
	2-methyl-2-phenylbutane
	3-ethyl-3-phenylpentane

11. Name the following aromatic hydrocarbons:

a. 

b. 

c. 

d. 

12. Draw structural diagrams for the following aromatic compounds:

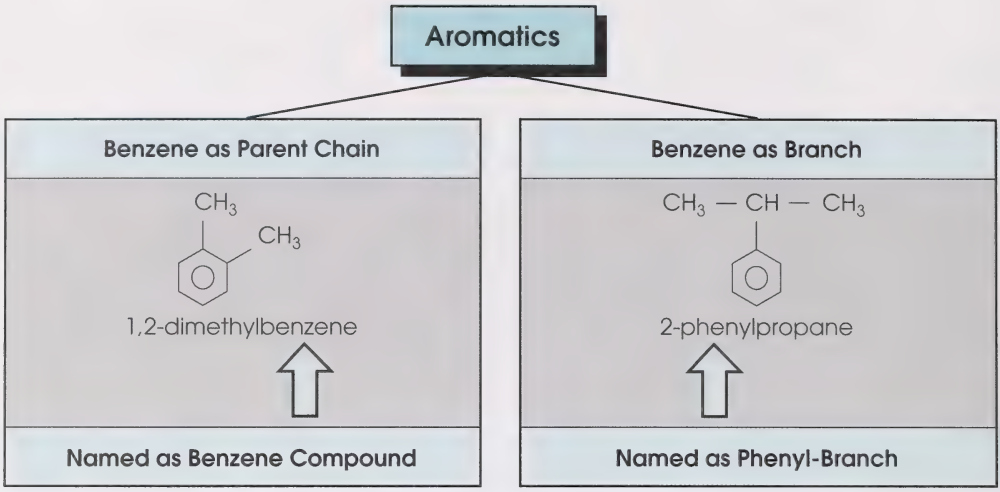
a. 2,3-dimethyl-5-phenylheptane

b. 1-phenyl-1-ethene (phenylethene)

c. 6-methyl-2,5-diphenylnonane

d. 3-phenyl-1-propyne

Check your answers by turning to the Appendix, Section 2: Activity 2.

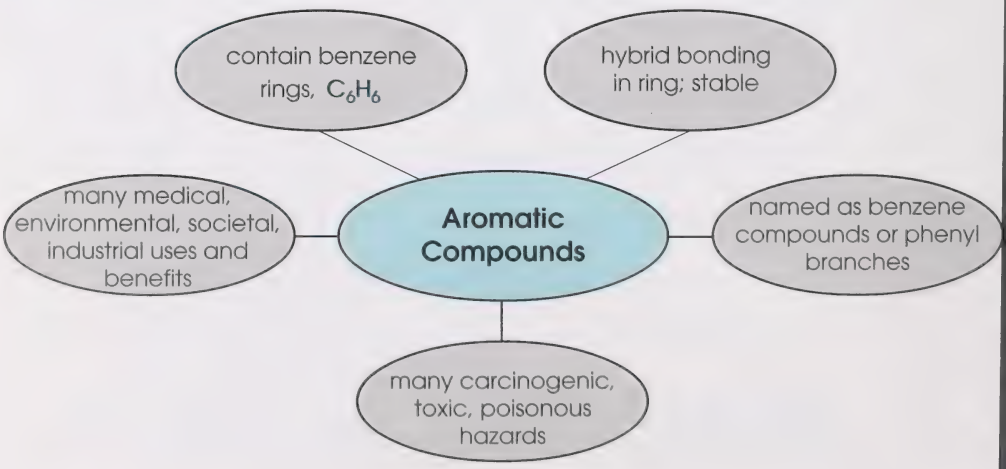


Aromatic compounds provide many vital products in society, but they also comprise many others which require considerable care in handling.

Follow-up Activities

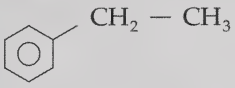
If you had difficulties understanding the concepts in the activities, it is recommended that you do the Extra Help. If you have a clear understanding of the concepts, it is recommended that you do the Enrichment.

Extra Help


contain benzene rings, C6H6
hybrid bonding in ring; stable
many medical, environmental, societal, industrial uses and benefits
Aromatic Compounds
named as benzene compounds or phenyl branches
many carcinogenic, toxic, poisonous hazards

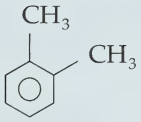
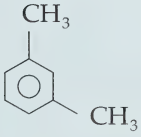
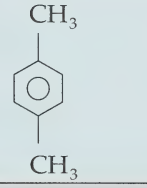
Aromatic Naming Summary

- If one alkyl group is bonded to a benzene molecule it is named as an alkylbenzene.

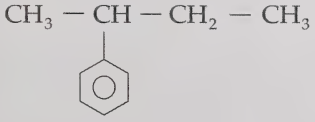


ethylbenzene (no number required)

- When two alkyl groups are bonded to a benzene molecule, the three possible isomers are named as alkylbenzenes using the lowest possible numbers to indicate the locations of the two alkyl groups. The classical *ortho-*, *meta-* and *para-* prefixes are also used to indicate the three possible 1,2; 1,3; or 1,4 isomer positions.

	1,2-dimethylbenzene orthodimethylbenzene o-dimethylbenzene
	1,3-dimethylbenzene metadimethylbenzene m-dimethylbenzene
	1,4-dimethylbenzene paradimethylbenzene p-dimethylbenzene

- The phenyl group identifies a molecule when the benzene molecule is considered as a branch rather than the parent chain.



2-phenylbutane

- The alkyl groups that bond to a benzene molecule are sometimes written as a molecular formula rather than a structural one.

Identify the best answer for each of the following multiple-choice questions.

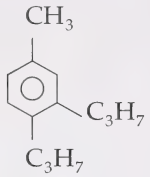
1. The carbon-carbon bonds in benzene are

   A. identical to the carbon-carbon bonds in cyclohexane

   B. identical to the carbon-carbon bonds in cyclohexene

   C. a hybrid between a double and single bonds

   D. easily broken in chemical reactions

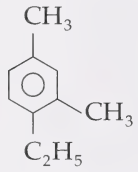
2. The name of  is

   A. 1-methyl-3,4-dipropylbenzene

   B. 1,2-dipropyl-4-methylbenzene

   C. 4-methyl-1,2-dipropylbenzene

   D. 3,4-dipropyl-1-methylbenzene

3. The name of  is

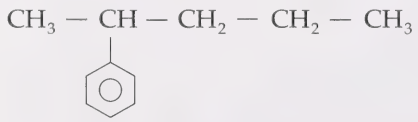
   A. 1,3-dimethyl-4-ethylbenzene

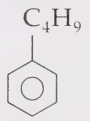
   B. 1-ethyl-2,4-dimethylbenzene

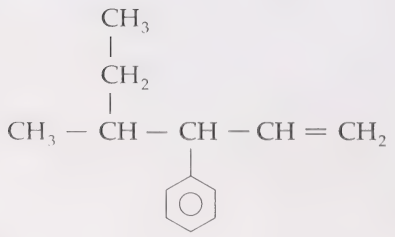
   C. 1,3-dimethylphenylbenzene

   D. o,p-dimethylethylbenzene

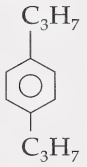
4. Name the following compounds:

   a. 

   c. 

   b. 

5. Give the two names of this compound:



6. Draw the structures for the following molecules:

   a. 1-butyl-3-ethylbenzene

   b. 1-methyl-3-pentylbenzene

   c. m-ethylmethylbenzene

Check your answers by turning to the Appendix, Section 2: Extra Help.

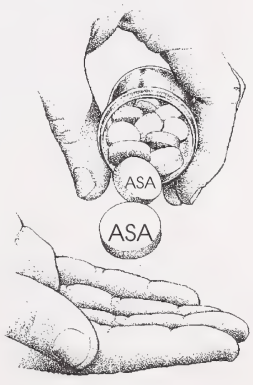
Enrichment

Do **one** of the following.

1. Using library research, write a report on the properties and industrial uses of one of the aromatics such as benzene, aniline, toluene, or xylene.

2. Construct models of benzene, aniline, toluene, and xylene using a molecular model kit or alternatives as shown in the module. Try to see how their main functional groups affect their properties.

3. Acetylsalicylic acid, ASA, is a benzene compound that revolutionalized the medical industry with its ability to reduce pain and inflammation. If you have access to the video series *Organic Chemistry 2* (ACCESS Network/TVO), view video segment 3, ASA, to see the history behind ASA, its structure and functions, and how its properties have helped society.



Check your answers by turning to the Appendix, Section 2: Enrichment.

Conclusion

You have discovered how aromatic hydrocarbons are a unique but important group of organic compounds. They are all based on the benzene molecule, C_6H_6, obtained from coal tar. Although benzene was isolated early in the 1800s, its structure was difficult to determine due to limitations in structural theories. The molecule is now considered to be a resonance hybrid which means that the carbon-carbon bonds are somewhere between single and double bonds.

Alkylbenzenes are formed whenever alkyl groups become bonded to a benzene molecule. When compounds contain benzene as a side chain or branch, they are named as phenyls.

With the introduction of compounds such as ASA, you have seen how special groups of atoms can affect a structure's properties. This will be explored further in the next section.

Assignment Booklet

ASSIGNMENT

Turn to Assignment Booklet 6B and do the assignment for Section 2.

SECTION 3

Hydrocarbon Derivatives

CITY OF EDMONTON PUBLIC WORKS

Do you enjoy sunbathing at a pool or in your backyard? Maybe you just like being outside on a sunny day. Have you noticed the numerous warnings by the media about possible health risks arising from exposure to ultraviolet radiation, or the dangers associated with ozone depletion by chlorofluorocarbons or CFCs?

Chlorofluorocarbons or CFCs are only one example of a large group of compounds known as hydrocarbon derivatives. These organic compounds provide industry and society with an enormous range of products. Each derivative is interesting in its own right with a unique set of uses and properties.

This section deals with the various categories and applications of hydrocarbon derivatives. You will discover their unique names and structures and gain a further understanding of the wide range of uses for these substances.

ACTIVITY

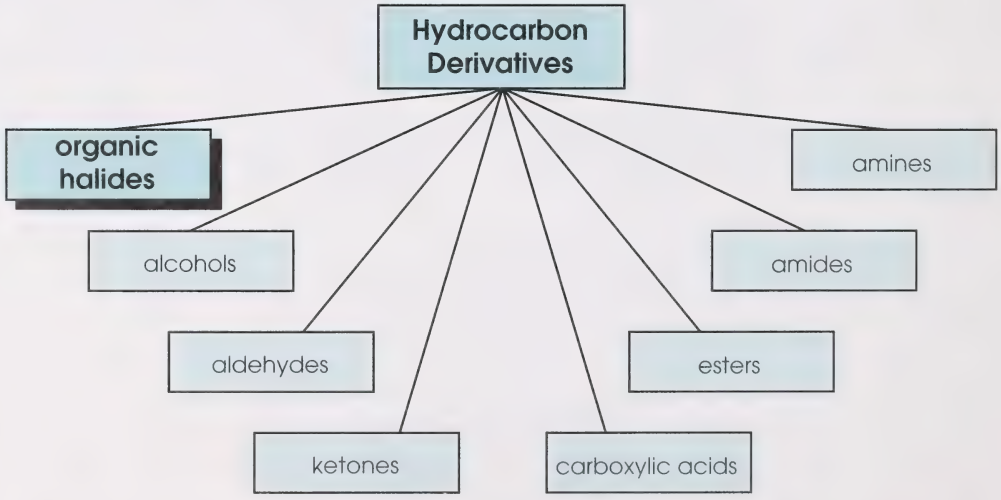
1 Organic Halides and Alcohols

DID YOU KNOW?

Medical research indicates that exposure to sunlight increases the risk of skin cancer. In 1935, 1 out of 1500 people developed skin cancer. By the year 2000 it is predicted that 1 out of 124 people will contract the disease. The only comfort in these alarming statistics is that the cure rate is about 95% when treated promptly.

That tan you are looking for may look healthy now but you could end up paying for it down the road. You could develop skin cancer or destroy the body's ability to fight off disease or infections. What is the cause for such alarming statistics?

Evidence suggests that large quantities of chlorofluorocarbons (CFCs) and other chemicals that have been introduced into the Earth's atmosphere in recent years are destroying much of the ozone, O_3, layer. Chlorofluorocarbons are in a class of hydrocarbon derivatives called organic halides. These compounds serve various uses required by society, but many must be handled with care.



Nelson CHEMISTRY

To learn more about organic halides, read the middle section and the margin notes on page 257 in your textbook.

1. What types of atoms distinguish the organic halides? Give examples.

2. What common examples of compounds are known as organic halides?

3. What are freons and where are they commonly used?

4. If CFCs are considered to be organic halides, what would their molecular composition look like?

5. Besides the potential destruction of the ozone layer, what other hazards are associated with many organic halides?

6. By monitoring CFC concentrations in the atmosphere, what evidence suggested to scientists the possibility that CFCs might be responsible for ozone depletion?

Check your answers by turning to the Appendix, Section 3: Activity 1.

Nelson CHEMISTRY

Note

In this section, you will be responsible for learning how to recognize the eight different hydrocarbon derivatives given by name and structure. It will therefore be important for you to refer to Table 9.1 on page 240 of your textbook from time to time for a review of the families of compounds.

For each hydrocarbon derivative, you will be given the general formula, structure, name, and examples for reference. Refer to Figure 6.7 as a guideline for completing the general information for each of the derivatives you will be studying.

The general information for organic halides is as follows:

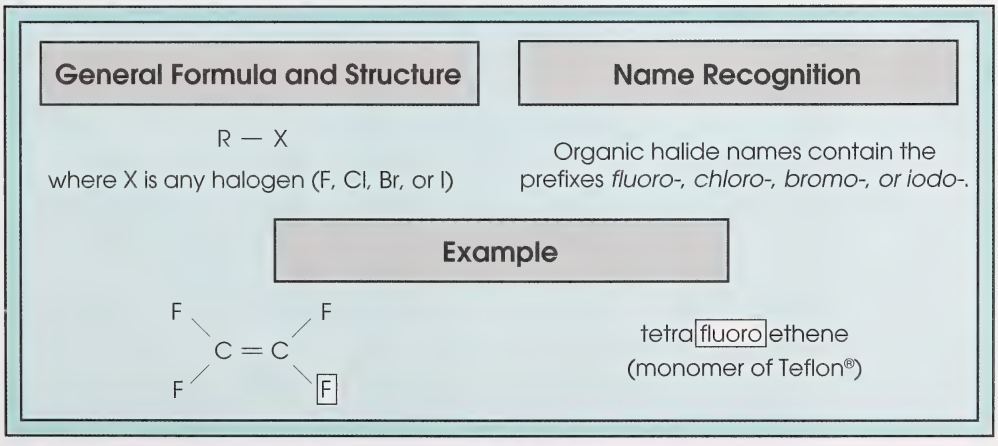


FIGURE 6.7: Organic Halides

7. a. What part of the compound name tells you that the substance is an organic halide?

   b. What part of the structure tells you that the compound is an organic halide?

The following table lists several organic halides and their uses.

IUPAC Name (common name in brackets)	Typical Technological Uses and Comments
a. trichloromethane (chloroform)	• discontinued anaesthetic
b. tetrachloromethane (carbon tetrachloride)	• discontinued fire extinguisher, solvent
c. triiodomethane (iodoform)	• antiseptic
d. chloroethene (vinyl chloride)	• PVC plastic monomer
e. dichloromethane (methylene chloride)	• paint remover
f. 1,4-dichlorobenzene (p-dichlorobenzene or paramoth)	• moth repellent, solid bathroom deodorizer
g. 1,2-dichloroethane	• drycleaning solvent
h. 1,1-dichloro-1,2,2,2-tetrafluoroethane (Freon 114)	• refrigerant for air conditioners and refrigerators
i. 2-bromo-2-chloro-1,1,1-trifluoroethane	• anaesthetic
j. 1,1,1-trichloroethane	• Scotchgard$_{TM}$ water repellent

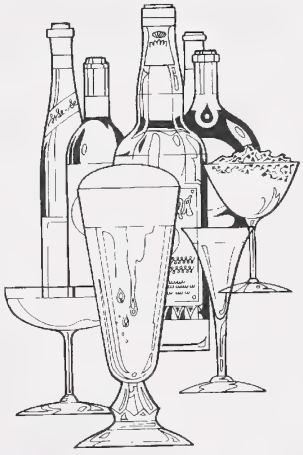
8. Optional: Draw condensed structural diagrams for each of the compounds listed in the preceding chart.

Check your answers by turning to the Appendix, Section 3: Activity 1.

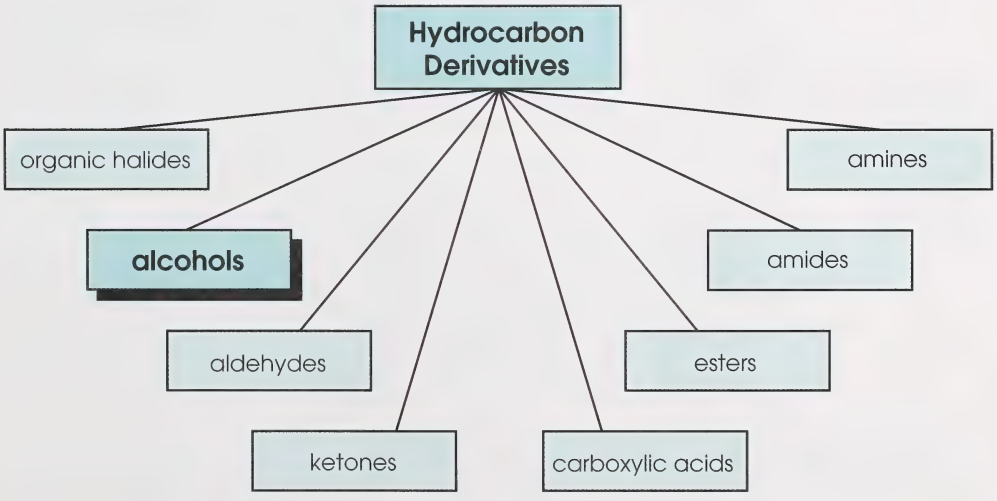
FIGURE 6.8: Alcohol Use

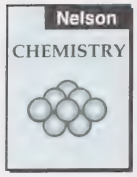
Figure 6.8 illustrates a common use of alcohol. What does the word *alcohol* mean to you? Is all alcohol safe to drink?

For most people, the word *alcohol* means ethanol or grain alcohol, C_2H_5OH, commonly found in beverages such as beer, wine, and spirits.



While many other alcohols make up a large number of organic compounds, you will find that few are safe for human consumption. Even ethanol is a poisonous alcohol with fatal results in excessive amounts. As well, several deaths or cases of blindness occur every year in Alberta from methanol or wood alcohol, CH_3OH, consumption.



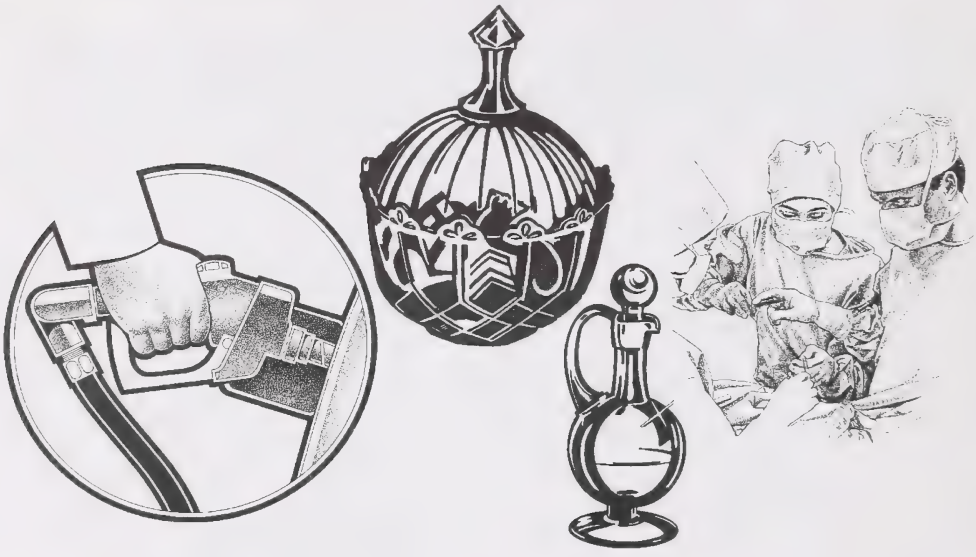


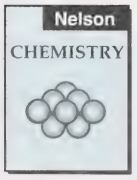
To discover the structure and properties of alcohols, read the first two paragraphs under the heading Alcohols on page 260 of your textbook.

9. What is a functional group?

10. What two properties of alcohols can be explained due to the hydrogen bonding they possess?

11. Why are alcohols widely used as industrial solvents for such products as perfumes, aftershave lotions, artificial flavourings, or many organic reactions?





To help you answer the question that follows, read the section from the third paragraph on page 260 to the middle of page 261 in your textbook.

DID YOU KNOW?

Phenol, C_6H_5OH, is an alcohol with the hydroxyl group bonded to a benzene ring. At one time it was called carbolic acid. It was first used by Sir Joseph Lister as a germacide in hospitals and during surgery. It has a typical "hospital odour" and is found in many household products such as disinfectant sprays and burn treatment ointments. It is also used to make some types of plastics.

12. Draw the structural diagram for phenol.

13. Refer to Figure 6.7: Organic Halides as a guideline and complete the general information for alcohols.

14. a. What part of the compound name tells you that the substance is an alcohol?

    b. What part of the structure tells you that the compound is an alcohol?

IUPAC Name (common name in brackets)	Typical Technological Uses and Comments
a. methanol (wood alcohol or methyl hydrate)	• varnish and windshield washer solvent, gas-line antifreeze, denaturant, fuel • made at one time by heating wood shavings • highly poisonous, used to denature ethanol to prevent its consumption
b. ethanol (grain or ethyl alcohol)	• important reagent for many synthesis reactions • solvent for flavourings, perfumes, varnishes, etc. • liquor and gasoline component • made by fermenting corn, wheat, rye, potatoes, etc.
c. 1-propanol (normal propyl alcohol)	• brake fluid, lacquer and wax solvent • starting material for many organic reactions
d. 2-propanol (isopropyl alcohol)	• rubbing alcohol • oil and gum solvent • starting material for many organic reactions
e. 2-butanol (secondary butyl alcohol)	• used to produce ketones and other organics • used as solvent, in paint removers, industrial cleaners, organic synthesis
f. 1-pentanol	• used in producing carboxylic acid and other organics

15. Optional: Draw a condensed structural diagram for each of the commonly used alcohols listed in the preceding chart.

Check your answers by turning to the Appendix, Section 3: Activity 1.

The following table summarizes information about organic halides and alcohols.

Class of Compounds	Functional Group	General Structure
Organic halides	F, Cl, Br, or I	R — X, where R is a hydrocarbon residue and X is a halogen
Alcohols	— OH	R — OH, where R is a hydrocarbon residue and OH is the hydroxyl group

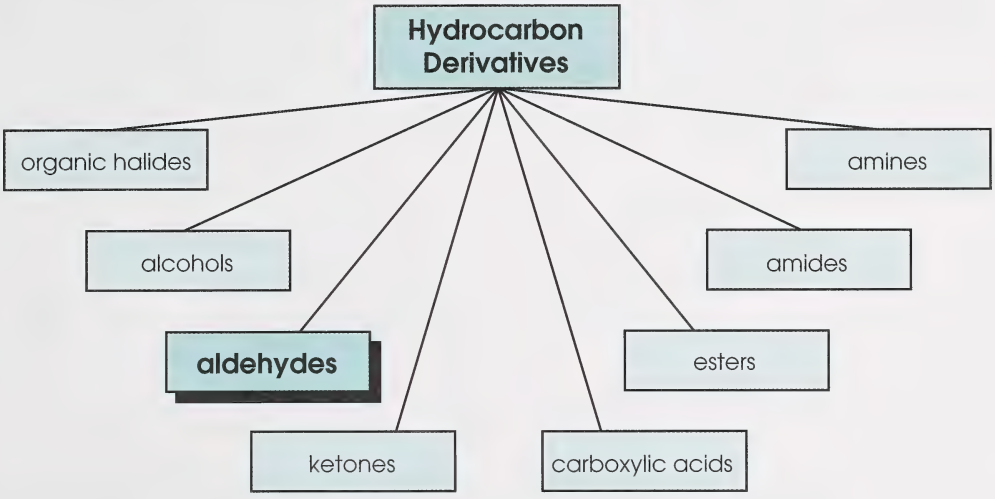
ACTIVITY 2

Aldehydes and Ketones

PHOTO SEARCH LTD.

Have you ever wondered why some perfumes are so expensive? A wide variety of them owe their existence to plant sources such as exotic jungle flowers. Some sources are rare enough to make only small amounts of exclusive and therefore expensive fragrances. Other fragrances owe their existence to organic compounds called aldehydes and ketones.

Aldehydes and ketones have different properties depending on the size of the molecule or molar mass. Aldehydes with large molar masses have fragrant odours while the smaller aldehyde molecules have very sharp, pungent, and irritating odours. Do you think similar properties would apply to ketones?



Nelson CHEMISTRY

To learn about the class of organic compounds called aldehydes, read the first two paragraphs and the margin notes on page 262 of your textbook and answer the following questions.

1. Refer to Figure 6.7: Organic Halides as a guideline and complete the general information for aldehydes.

2. a. What part of the compound name tells you that the substance is an aldehyde?

   b. What part of the structure tells you that the compound is an aldehyde?

3. What property could be used to identify smaller aldehydes and why would the evidence be inconclusive?

4. What are some present and past common uses for methanal or, as it was once called, formaldehyde?

5. What are some common uses for ethanal or, as it was once called, acetaldehyde?

Check your answers by turning to the Appendix, Section 3: Activity 2.

DID YOU KNOW?

Benzaldehyde, C_6H_5CHO, is an aldehyde with the carbonyl group bonded to a benzene ring. It is found in almonds and is known as "oil of bitter almond" but can be made from toluene. It is commonly used by the perfume and flavouring industry in soaps, perfumes, deodorants, synthetic penicillin, wild oats herbicides, and cherry flavours.

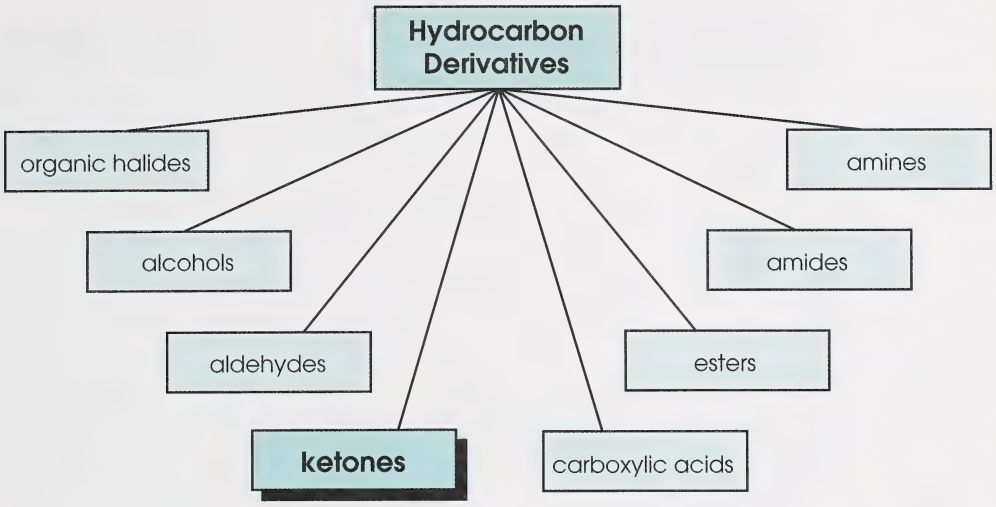
6. What is the structural formula for benzaldehyde, the simplest aromatic aldehyde?

The following table illustrates several examples of aldehydes. Study the information.

IUPAC Name (common name in brackets)	Typical Technological Uses and Comments
a. methanal (formaldehyde)	• sharp, irritating odour • discontinued preservative for biological specimens • used to produce urea formaldehyde foam insulation, Bakelite® plastic
b. ethanal (acetaldehyde)	• cause of alcohol hangover symptoms • starting material for making many organics, industrial solvent
c. propanal (propionaldehyde)	• special solvent and intermediate in making printing inks for plastics
d. butanal (butraldehyde)	• prolongs life of rubber products • used in producing dyes, ethers, alcohols, synthetic resins, plasticizers

7. Optional: Draw a condensed structural diagram for each of the aldehydes listed in the preceding chart.

Check your answers by turning to the Appendix, Section 3: Activity 2.



Nelson CHEMISTRY

Ketones are a very close relative of aldehydes. To learn about ketones, read the last paragraph on page 262 and the top paragraph and margin notes on page 263 of your textbook.

8. How do ketones differ from aldehydes?

9. What chemical property is affected by the position of a carbonyl group in ketones?

10. What is the simplest ketone and what are some of its uses?

DID YOU KNOW?

Propanone, CH_3COCH_3, also called acetone, is widely used as a universal organic solvent comparable to water for inorganic compounds. North American use exceeds one million tonnes annually.

Frames 7838-12104

If you have access to the laser videodisc *Cosmic Chemistry*, find and view the sequence frames 7838-12104, chapter 8, side 2. This sequence shows acetone as a solvent with polystyrene. It gives you an example of one of the properties of ketones.

11. Refer to Figure 6.7: Organic Halides as a guideline and complete the general information for ketones.

12. a. What part of the compound name tells you that the substance is a ketone?

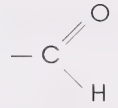
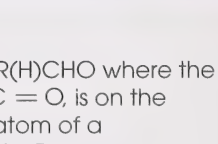
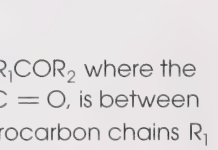
    b. What part of the structure tells you that the compound is a ketone?

Check your answers by turning to the Appendix, Section 3: Activity 2.

DID YOU KNOW?

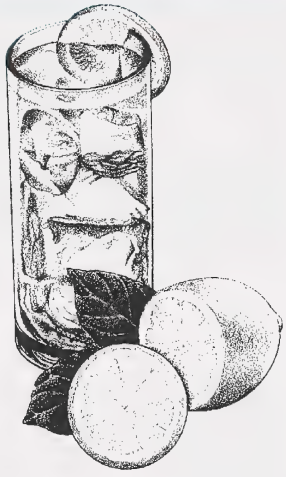
Muscone, an expensive perfume ingredient, is obtained from the scent glands of the male musk deer. Testosterone, a male sex hormone, is another example of a ketone.

In the activity just completed, you have learned about aldehydes and ketones. The following table summarizes both compounds.

Class of Compounds	Functional Group	General Structure
Aldehydes		 R(H) — C — H or R(H)CHO where the carbonyl group, C = O, is on the terminal carbon atom of a hydrocarbon chain, R (If the compound only contains one carbon, R is replaced by an H.)
Ketones		 R_1 — C — R_2 or R_1COR_2 where the carbonyl group, C = O, is between two different hydrocarbon chains R_1 and R_2

ACTIVITY

3 Organic Acids and Esters

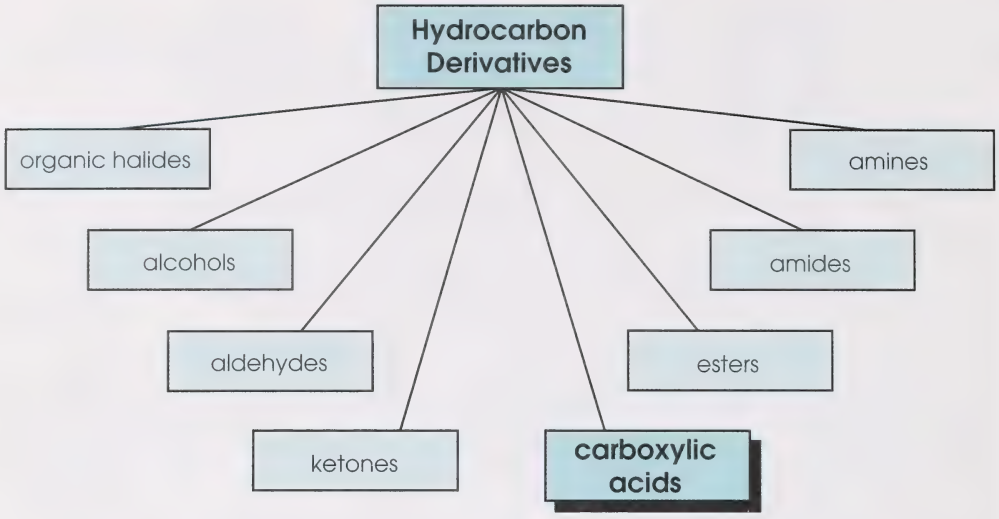


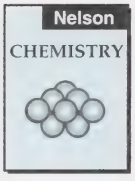
Do you enjoy a touch of vinegar on your french fries, potato chips, or brussel sprouts?

Do you like to eat lemons or enjoy their flavour in lemon drinks?

Did you know that lemon is the world's leading scent based on surveys made by the detergent and soap industry? This may explain the wide use of "lemon fresh" household cleaners. It may even explain why you or someone you know may prefer lemon pie over other kinds.

One common property that vinegar and lemons have in common is a sour taste due to the carboxylic acids which they contain. Although many plants such as rhubarb, cabbage, and citrus fruits contain carboxylic acids, other carboxylic acids are obtained from animal sources. But what are carboxylic acids?





To learn more about carboxylic acids, read the description, including the margin notes, from the top of page 263 to the middle of page 264 in your textbook and answer the questions that follow.

1. What two functional groups do carboxylic acids contain?

2. What are the common sources of carboxylic acids?

3. What carboxylic acid property distinguishes a lemon from a banana?

4. What are some common carboxylic acids properties?

5. What common test can be used to identify carboxylic acids from other hydrocarbon derivatives?

6. What are some common uses for methanoic or formic acid?

7. How do oxalic, tartaric, and citric acids differ? What are some of their common uses?

8. How are tracking dogs able to detect the scent produced by different people?

9. Refer to Figure 6.7: Organic Halides as a guideline and complete the general information for carboxylic acids.

10. a. What part of the compound name tells you that the substance is a carboxylic acid?

    b. What part of the structure tells you that the compound is a carboxylic acid?

DID YOU KNOW?

Many carboxylic acids were first obtained from fats found in natural sources and are therefore also referred to as "fatty acids." Common names were assigned to these fatty acids according to the natural sources from which they were obtained rather than their structure. For example, butyric acid (Latin *butyrum* = butter) is the fatty acid responsible for the rancid smell of aging butter.

The following table gives you some other examples of carboxylic acids and their uses.

IUPAC Name (common name in brackets)	Typical Technological Uses and Comments
a. methanoic acid (formic acid)	• found in the sting of ants, bees, and nettles • food and pharmaceutical preservative • used in textile industry • used to remove hair from hides during tanning • rubber coagulant
b. ethanoic acid (acetic acid)	• main vinegar ingredient • textile dyeing mordant (fixes or sets dye colour) • industrial solvent and starting material for many organics
c. propanoic acid (propionic acid)	• used by baking industry to prevent growth of mold in bread and pastry
d. butanoic acid (butyric acid)	• putrid odour of rancid butter • used to make artificial flavours such as rum and butter, pineapple, etc.
e. pentanoic acid (valeric acid)	• blue cheese flavour
f. hexanoic acid (caproic acid)	• Limburger (cheese) and goat odour
g. benzoic acid	• used to make sodium benzoate, a common food preservative

11. Optional: Draw a condensed structural diagram for each of the carboxylic acids listed in the preceding chart.

Check your answers by turning to the Appendix, Section 3: Activity 3.

DID YOU KNOW?

Formic or methanoic acid was first obtained from the distillation of crushed red ants. So then, is methanoic acid really an "ant" acid? Similarly, the Latin name for butter is *butyrum* from which butyric or butanoic acid was obtained. The prefix for four carbon atoms, *but-* explains its origin.

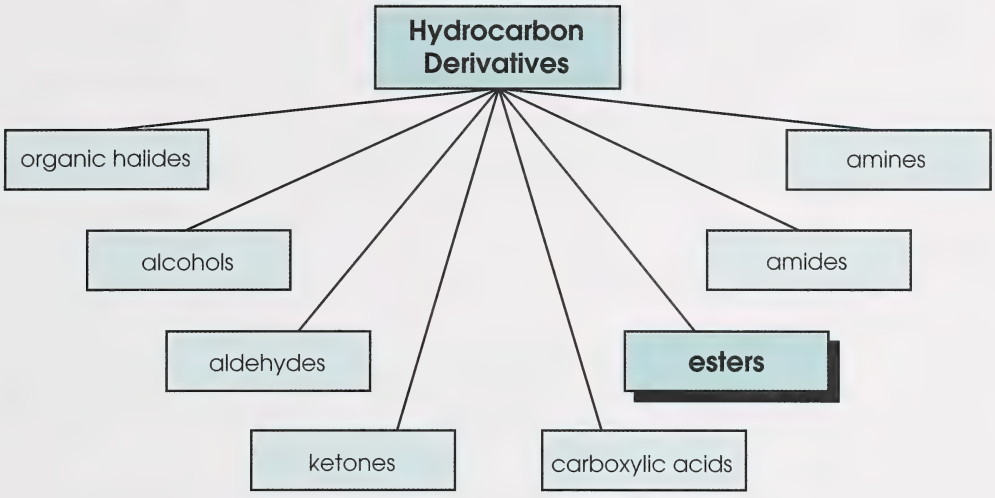
WESTFILE INC.

If you performed a blindfolded taste test of different fruits, could you tell the difference between a bite of apple and a bite of cherry? You would probably tell the difference easily.

What makes a strawberry different from a raspberry, or an apricot different from a peach? Is your favourite milkshake flavour derived from natural sources or is it an imitation synthetic such as rum and butter?

Besides shapes and colours, different fruits have distinct and unique flavours and aromas. Flowers can also be identified by their unique fragrances. But did you ever stop to consider what chemicals are responsible for the taste you enjoy in a certain fruit or the aroma that identifies your favourite flower?

The chemicals which produce different flavours in fruit or fragrance in flowers belong to a class of organic compounds called esters. Esters give plants such as garlic and onion their characteristic flavours and aroma as well. Natural esters are a product of the reaction between alcohols and carboxylic acids, each of which you have already studied.



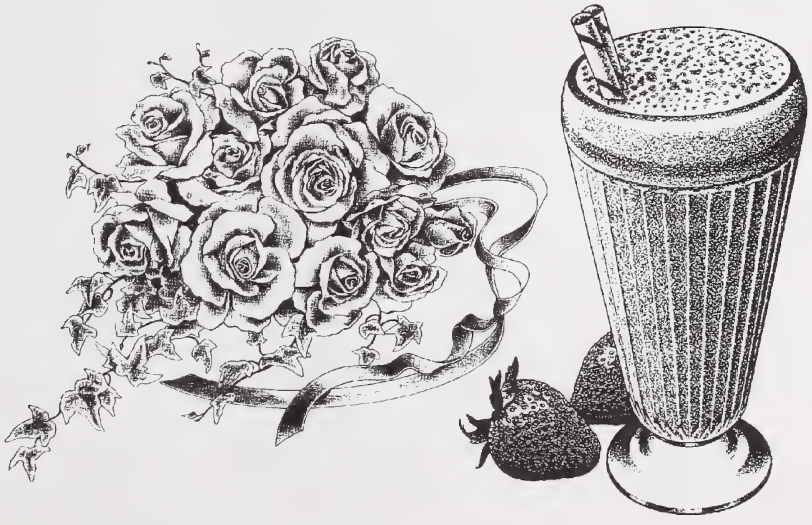
Nelson CHEMISTRY

Read the last two paragraphs on page 264 of your textbook to learn more about esters and answer the questions that follow.

12. How do esters differ from carboxylic acids?

13. What property do plants possess because of esters?

14. What are some common uses for esters?



15. Describe the origin of each part in an ester name.

16. Refer to Figure 6.7: Organic Halides as a guideline and complete the general description of esters.

17. a. What part of the compound name tells you that the substance is an ester?

    b. What part of the structure tells you that the compound is an ester?

The following table illustrates some common esters and their uses.

IUPAC Name (common name in brackets)	Typical Technological Uses and Comments
a. 2-butyl ethanoate (isobutyl acetate)	• strawberry flavour
b. ethyl ethanoate (ethyl acetate)	• fingernail polish remover
c. butyl ethanoate (butyl acetate)	• raspberry flavour
d. 2-butyl benzoate (isobutyl benzoate)	• florals and caraway flavours
e. 2-butyl propanoate (isobutyl propionate)	• rum flavour
f. ethyl butanoate (ethyl butyrate)	• pineapple flavour
g. 1-pentyl ethanoate (amyl acetate)	• pear odour
h. 2-pentyl ethanoate (isoamyl acetate)	• banana odour • carrier for aluminum paint

18. Optional: Draw the condensed structural diagrams for each of the esters listed in the preceding chart.

Check your answers by turning to the Appendix, Section 3: Activity 3.

Frames 31048-36340

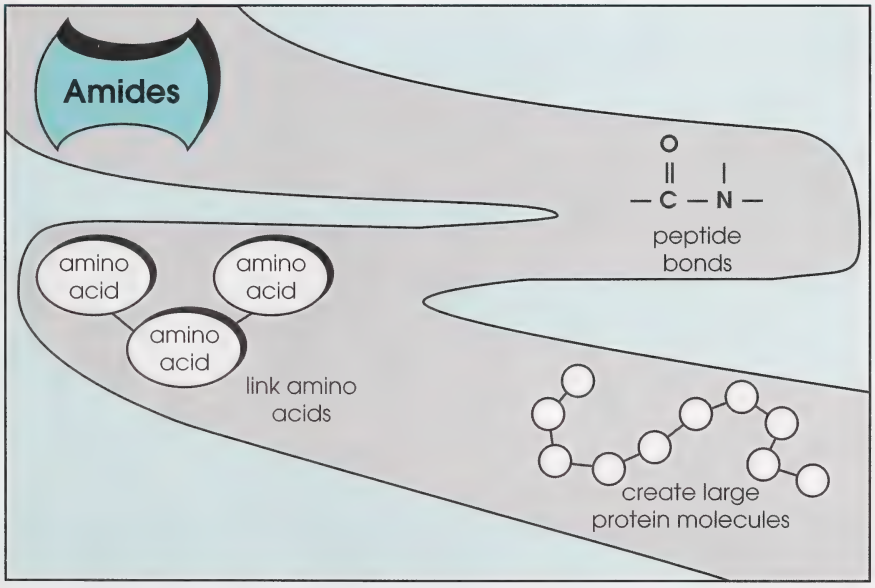
Perfumes are often made of low-mass esters obtained from flowers. If you have access to the laser videodisc *Cosmic Chemistry*, find and view the sequence frames 31048-36340, chapter 22, side 6. This sequence looks at the production of perfume from the initial ester extraction to the creation of scents.

In the activity just completed, you have learned about carboxylic acids and esters. Like aldehydes and ketones, both compounds also contain the C = O carbonyl functional group, but the arrangement differs. Study the following table.

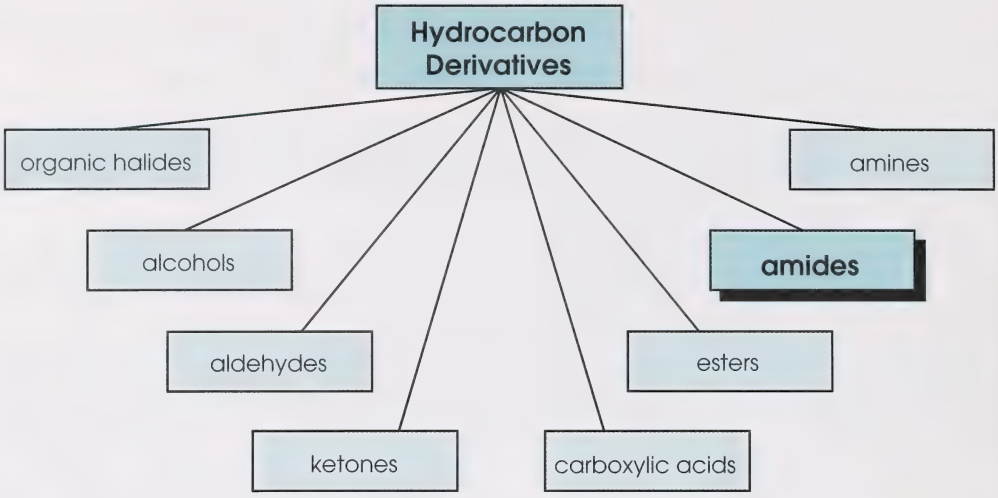
Class of Compounds	Functional Group	General Structure
Carboxylic acids	O || — C — OH	O || R(H) — C — OH or R(H)COOH
Esters	O || — C — O —	O || R_1(H) — C — OR_2 or R_1(H)$COOR_2$

ACTIVITY

4 Amides and Amines



Have you ever wondered what holds you together? How does your body create all those wonderful muscles that make everything work? The factor largely responsible for these necessary connections are peptide bonds. These bonds are the amide linkages that hold the amino acids in proteins together.



Nelson CHEMISTRY

Read the section Amides on page 266 in your textbook to learn more about amides. Answer the questions that follow.

1. a. What does the amide functional group consist of?

   b. Where is the amide functional group usually found or occur?

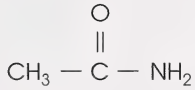
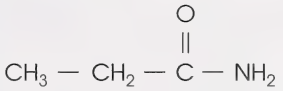
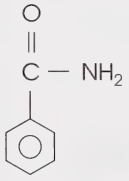
2. What is a peptide bond and what is its function?

3. Refer to Figure 6.7: Organic Halides as a guideline and complete the general description of amides.

4. a. What part of the compound name tells you that the substance is an amide?

   b. What part of the structure tells you that the compound is an amide?

The following table provides a brief description of some amide compounds.

IUPAC Name (common name in brackets)	Structural Formula	Typical Technological Uses and Comments
a. methanamide (formamide)	_____	• intermediate in organic synthesis • solvent, softener
b. _____ (acetamide)		• wetting agent (allows liquid to spread over or penetrate into surface) • used in lacquers and explosives
c. _____ (propionamide)		• N/A
d. butanamide (butyramide)	_____	• N/A
e. pentanamide (valeramide)	_____	• N/A
f. _____		• organic synthesis

5. Optional: Fill in the missing IUPAC names or structures where applicable in the preceding chart.

substituents – atoms or groups of atoms replacing other atoms or groups in compounds

Amides are also classified according to the number of **substituents** bonded to the nitrogen atom in an amino group ($-NH_2$) as illustrated in Figure 6.9.

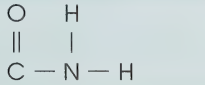
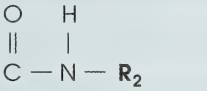
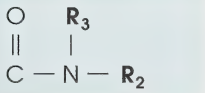
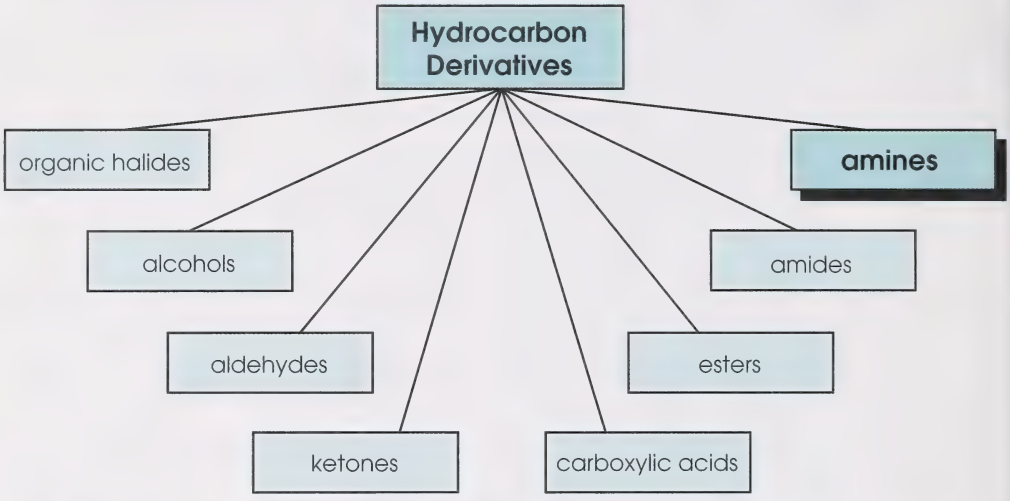
Primary Amide	Secondary Amide	Tertiary Amide
		

FIGURE 6.9: Classification of Amides

6. How many hydrocarbon (alkyl) groups are bonded to the central nitrogen atom in each of the following?

   a. a primary amide? b. a secondary amide? c. a tertiary amide?

Check your answers by turning to the Appendix, Section 3: Activity 4.



COURTESY OF GUY G. AND KAY CUBITT

Is fishing one of your favourite pastimes? Can you recognize the odour of fish readily, especially if the fish has not been refrigerated? What compounds are responsible for producing the odour?

Amines, characterized by a fishlike odour, are a group of ammonia, NH_3, derivatives. Like the amides, amines contain a single-bonded nitrogen atom. The only difference is that amines do not have a double-bonded oxygen atom common to amides.

Nelson CHEMISTRY

To learn more about the structure and properties of amines, read the section Amines on page 266 in your textbook and answer the questions that follow.

7. Describe the structure of an amine.

8. What physical property is common to amines?

Amines are classified according to the number of alkyl groups or hydrocarbon chains (R) attached to the central nitrogen atom as illustrated in Figure 6.10.

Primary Amine	Secondary Amine	Tertiary Amine
$R_1 - NH_2$	$R_1 - \underset{\displaystyle H}{\underset{\displaystyle \vert}{N}} - R_2$	$R_1 - \underset{\displaystyle R_3}{\underset{\displaystyle \vert}{N}} - R_2$

FIGURE 6.10: Classification of Amines

9. Indicate how many alkyl groups or hydrocarbon residues are bonded to the central nitrogen atom in each of the following.

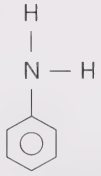
   a. a primary amine b. a secondary amine c. a tertiary amine

10. Refer to Figure 6.7: Organic Halides as a guideline and complete the general description for amines.

11. a. What part of the compound name tells you that the substance is an amine?

    b. What part of the structure tells you that the compound is an amine?

Amines have a wide range of applications. Study the following table which illustrates some of the uses of amine compounds.

IUPAC Name	Condensed Structural Formula	Typical Technological Uses and Comments
a. _____	$CH_3 - NH_2$	• flammable gas, solvent • used in producing dyes and insecticides
b. ethylamine	_____	• colourless, volatile liquid • used in petroleum refining, detergents, organic synthesis
c. diethylamine	_____	• rubber chemicals, textiles and dyes, pesticides, drugs, electroplating
d. dimethylamine	_____	• gas absorbent, solvent, textile chemicals, rocket propellant, missile fuel
e. _____	$CH_3 - N(CH_3) - CH_3$	• insect attractant, organic synthesis of disinfectants, plastics
f. methylpropylamine	_____	• N/A
g. butylamine	_____	• intermediate emulsifying (light-sensitive coating) and tanning agent • makes dyes, drugs, insecticides
h. _____		• oily, colourless, poisonous benzene derivative • used to make rubber, dyes, resins, varnishes, pharmaceuticals

12. Optional: Fill in the missing names or structures as required in the preceding table.

Check your answers by turning to the Appendix, Section 3: Activity 4.

In the activity just completed, you have learned about amides and amines. Both compounds contain a single bond to a nitrogen atom as summarized in the following table.

Class of Compounds	Functional Group	General Structure
Amides	$CO + NH_2$ (carbonyl + amino)	$R_1(H)-C(=O)-N(R_2(H))-R_3(H)$
Amines	$-NH_2$ (amino group)	$R_1-N(R_2(H))-R_3(H)$

Follow-up Activities

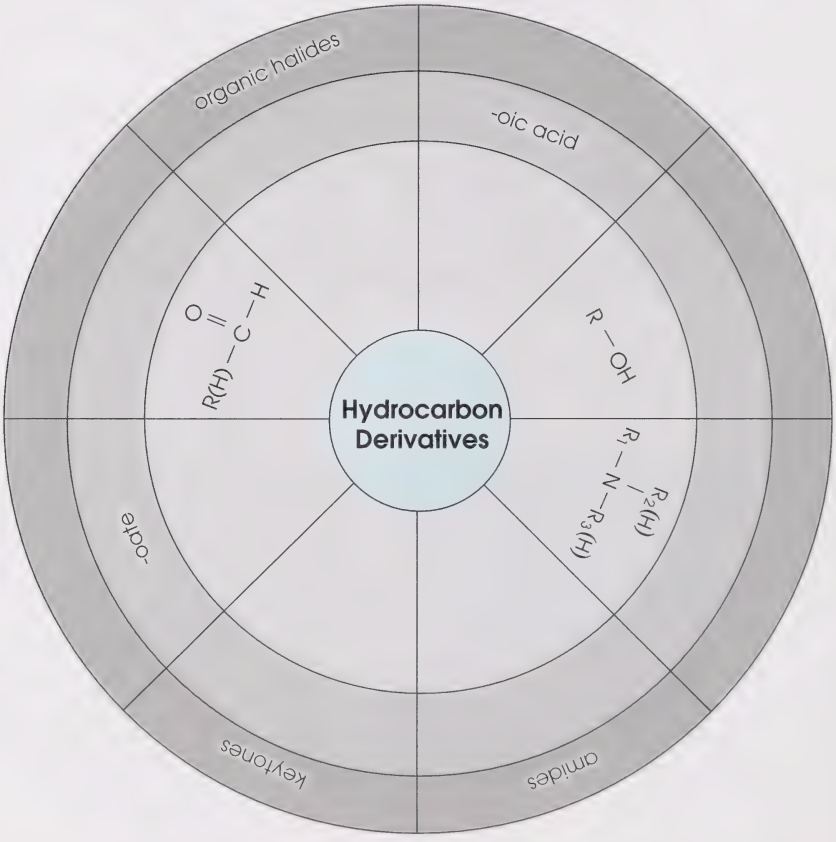
If you had difficulties understanding the concepts in the activities, it is recommended that you do the Extra Help. If you have a clear understanding of the concepts, it is recommended that you do the Enrichment.

Extra Help

Hydrocarbon derivatives contain atoms or groups of atoms, other than hydrogen and carbon, called functional groups. The specific arrangements of these atoms in organic compounds are responsible for the chemical similarities that a large number of organic families possess.

Refer to Table 9.1 on page 240 in your textbook to review the families of organic compounds.

1. Supply the missing information in the following hydrocarbon derivative wheel.



2. Complete textbook question 20 (a-e) in the exercise on page 268 of your textbook.

Check your answers by turning to the Appendix, Section 3: Extra Help.

Enrichment

Do **one** of the following.

1. Using library research, write a report on the function and use of freons in air conditioners, refrigerators, and propellants.

2. Visit a local brewery or use library research to write a report on the production and uses of ethanol or grain alcohol.

3. Using library research, write a report on how aldehydes and ketones determine the types of carbohydrates found in natural sources.

4. Use library research or talk to a research biochemist to write a report on amino acids and their function in the formation of proteins.

Check your answers by turning to the Appendix, Section 3: Enrichment.

Conclusion

In this section, you have discovered the tremendous variety of organic compounds created by varying the atoms of a functional group. With the addition of oxygen, nitrogen, and the halogens to a hydrocarbon base, compounds varying from Teflon® to proteins can be created. You have seen as many natural sources as synthetic ones for many of the organics, which points to a need to protect the natural environment.

Assignment Booklet

ASSIGNMENT

Turn to Assignment Booklet 6B and do the assignment for Section 3.

MODULE SUMMARY

Organic chemistry is a vast and ever-growing field of chemistry. New compounds to suit various purposes are being synthesized every day. So far, you have had just a glimpse into the great variation of organic compounds possible, due to the uniqueness of carbon and the concept of isomerism.

A discussion of organic reactions lies ahead of you in Module 7.

Appendix

Glossary

Suggested Answers

Glossary

aliphatic: nonaromatic hydrocarbons

alkyl groups: hydrocarbon chains of the formula C_nH_{2n+1} that act as branches

arene: an aromatic hydrocarbon or a derivative of an aromatic hydrocarbon

aromatic: an organic compound containing benzene or benzene-like ring structures

disubstitution: the substitution of two hydrogen atoms on a benzene ring by two other atoms or groups of atoms

expanded molecular formulas: chemical formulas that illustrate the type, number, and groupings of atoms in molecules

functional group: a specific atom or group of atoms within a compound that gives the compound its characteristic properties

homologous series: a series of compounds with similar functional groups that differ from each other in a systematic, regular fashion

hybrid: a cross or combination of two or more different structures

hydrocarbons: any molecules containing only hydrogen and carbon atoms

isomers: compounds with the same molecular formula but different structural formulas

models: representations in three dimensions of physical objects or things

molecular formula: a chemical formula that indicates the type and number of atoms present in a molecule

polyunsaturates: long chain hydrocarbons with many multiple carbon bonds

saturated: organic compounds containing only single carbon-carbon bonds and the maximum number of bonded atoms

structural diagrams: spatial representations showing the type, number, and arrangement of atoms in molecules

substituents: atoms or groups of atoms replacing other atoms or groups of atoms in compounds

unsaturated: compounds containing multiple carbon-carbon bonds

Suggested Answers

Section 1: Activity 1

1. The organic compounds illustrated in Figure 6.1 are similar because they contain carbon.

2. Perfumes, some explosives, dyes, grease, oil, and gasoline are considered to be organic because they contain carbon.

3. Since carbon is located in Group 14 or IVA of the periodic table, it is a nonmetal and it has four bonding electrons.

4. A nonmetal element that would be expected to have properties similar to carbon is silicon.

5. Organic compounds contain covalent bonds within their molecules.

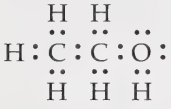
6. The ionic compounds which contain carbon but are not considered organic include carbonates (CO_3^{2-}), hydrogen carbonates (HCO_3^-), cyanides (CN^-), cyanates (OCN^-), and thiocyanates (SCN^-). These compounds contain ionic bonds rather than covalent bonds.

7. The molecular compounds containing carbon which are not considered organic molecules include carbon dioxide (CO_2), and carbon monoxide (CO).

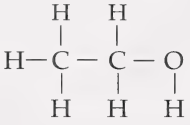
8. The unique bonding properties of carbon that make it ideal for forming so many organic compounds include the fact that it can form the following:

   - four covalent bonds
   - any size of chain, ring, sheet, sphere, and tube molecules
   - compounds with single, double, and triple covalent bonds

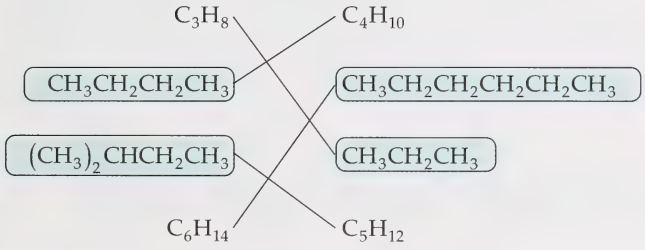
9. A Lewis model of ethanol will look as follows:



A structural formula of ethanol will look as follows:



10.



11. a. Isomers are compounds that have the same molecular formula but different structural formulas.

    b. The three structural isomers of C_5H_{12}, using condensed structural diagrams are as follows:

$$CH_3 - CH_2 - CH_2 - CH_2 - CH_3$$

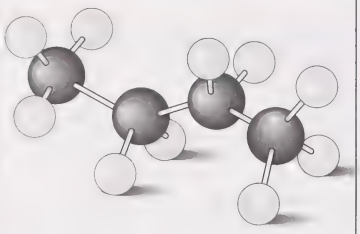
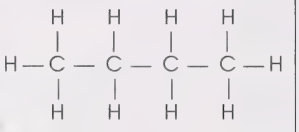
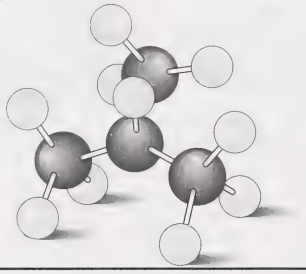
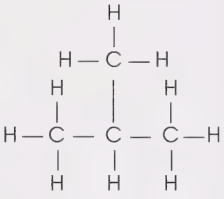
$$CH_3 - CH_2 - \underset{\displaystyle CH_3}{\underset{|}{CH}} - CH_3$$

$$CH_3 - \underset{\displaystyle CH_3}{\underset{|}{\overset{\displaystyle CH_3}{\overset{|}{C}}}} - CH_3$$

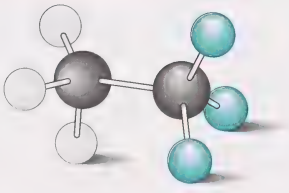
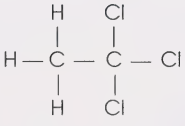
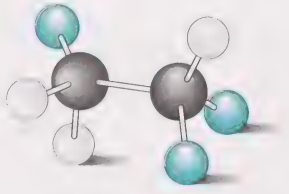
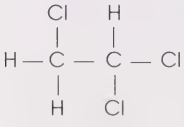
12. The two types of models are the ball-and-stick model and the space-filling model. The ball-and-stick model shows types of covalent bonds and bond angles. The space-filling model shows the general shape of the molecule.

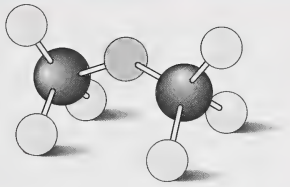
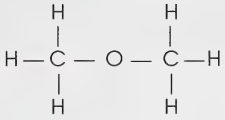
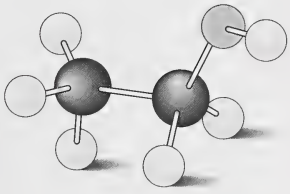
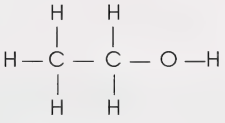
13. A complete structural diagram shows all the atoms and bonds in a structure. The condensed structural diagram shows all the atoms, but only the carbon-carbon bonds. A line structural diagram used to illustrate long molecules only shows lines representing carbon-carbon bonds.

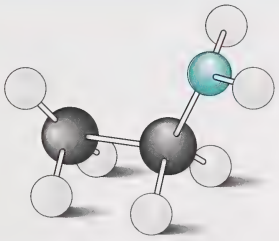
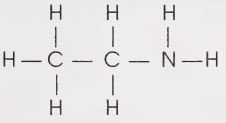
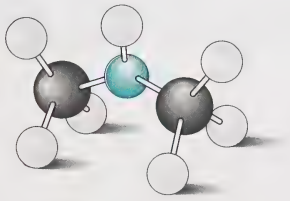
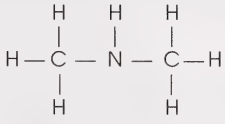
14. The structures for each of the molecular formulas will look as follows:

C_4H_{10}	Complete Structure	Condensed Structure	Line Structure
		$CH_3 - CH_2 - CH_2 - CH_3$	
		CH_3 | $CH_3 - CH - CH_3$	

Remember, for structures such as the second isomer of C_4H_{10}, it does not matter whether you draw the $-CH_3$ branch on the middle carbon above or below – it's the same substance (just think of turning the model over in your hand). What does matter is that the $-CH_3$ branch is attached to the middle carbon of the structure.

$C_2H_3Cl_3$	Complete Structure	Condensed Structure
		$CH_3 - CCl_3$
		$CH_2Cl - CHCl_2$

C_2H_6O	Complete Structure	Condensed Structure
		$CH_3 - O - CH_3$
		$CH_3 - CH_2 - OH$

C_2H_7N	Complete Structure	Condensed Structure
		$CH_3 - CH_2 - NH_2$
		$CH_3 - NH - CH_3$

15. a. A is not a true isomer.

    b. B is a true isomer.

    c. C is a true isomer; it is also the same isomer as B.

    d. D is a true isomer.

    e. E is not a true isomer.

16. The different functional groups distinguish one compound from another in their general formulas.

17. *R* stands for any carbon chain with the associated hydrogen atoms (alkyl group).

18.

Elements in Functional Groups	Bonding Capacity
* chlorine, Cl	1
oxygen, O	2
nitrogen, N	3

* **Note:** The other halogens F, Br, and I are also used in organic compounds.

19.

Inorganic Materials	Organic Materials
baking soda ammonia drain cleaner table salt water 16-20-0 fertilizer	vinegar pesticide lighter fluid perfume rubbing alcohol ASA tablets cooking oil bar of soap

Section 1: Activity 2

1. The composition of crude oil or petroleum is a mixture of many hydrocarbons.

2. Crude oil components can be separated from each other in a refinery because the fractions have different boiling points.

3. The petroleum fractions used for heating purposes include natural gas, naphtha, kerosene, and light gas oil or diesel fuel.

4. Answers may vary. The properties that make asphalt an ideal roofing or road paving material could include the fact that it can be poured when heated, it is a soft solid with some elasticity, it can be shaped into a smooth surface, and it does not dissolve in water.

5. Answers may vary. The properties of petroleum ether that make it an ideal material for cleaning fabrics could include the fact that it is a non-polar solvent and therefore can remove non-polar stains.

6. If an international body or committee decides on the rules for naming compounds, then it is likely that people the world over will be able to use the rules and name compounds.

7.

Prefixes	Number of Carbon Atoms
meth-	1
eth-	2
prop-	3
but-	4
pent-	5
hex-	6
hept-	7
oct-	8
non-	9
dec-	10

8. a. A branch is a carbon chain that is attached to the main chain of a hydrocarbon compound.

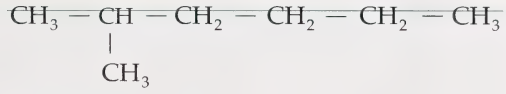
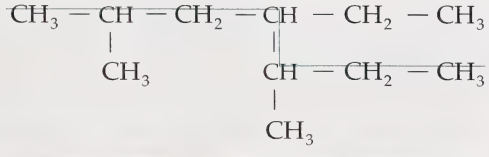
   b. The branch name has a *-yl* ending to distinguish it as a branch.

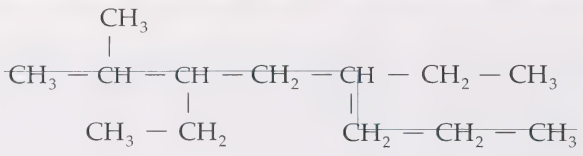
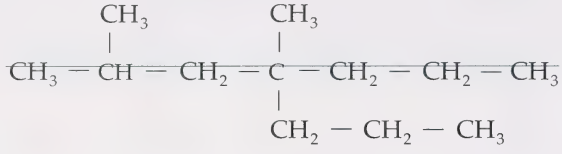
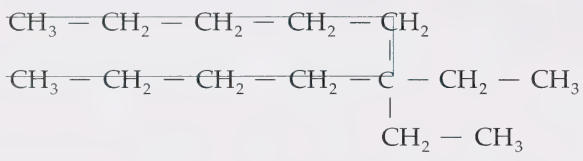
   c. All alkane compounds have names ending in *-ane*.

9. a. $C_{11}H_{24}$ b. $C_{26}H_{54}$ c. $C_{30}H_{62}$ d. $C_{54}H_{110}$

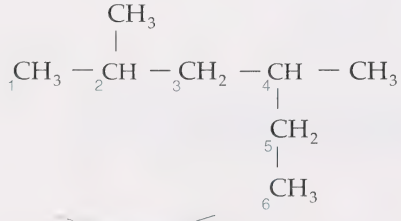
10. The parent chain is numbered from the end that gives the branches the lowest possible locating numbers.

11.

Structural Diagram	Name of Parent Chain
	hexane
	heptane

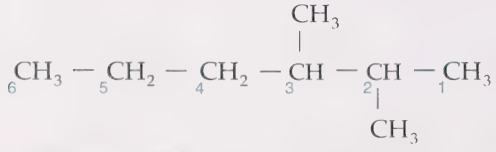
	octane
	heptane
	decane

12. a. 2-methylpentane
    b. 2,2-dimethylpropane
    c. 2,3,5-trimethylheptane
    d. 2,2,4,4-tetramethylhexane
    e. 2,2,4-trimethyl-4-propyloctane

13. a. 

    4-ethyl-2-methylpentane

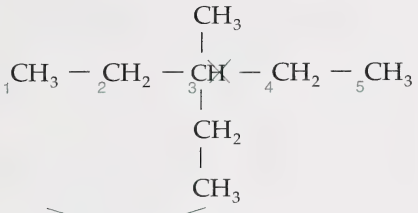
    The name does not reflect the longest continuous chain. The correct name should be 2,4-dimethylhexane.

    b. 

    4,5-methylhexane

    The main chain was numbered from the wrong end. Therefore, the name is wrong. The *di-* prefix in front of methyl is also missing. The correct name should be 2,3-dimethylhexane.

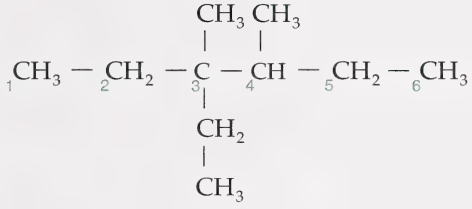
c.



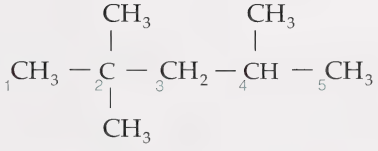
~~3-methyl-3-ethylpentane~~

Carbon No. 3 has too many bonds – the H should be removed. The branch names are not in alphabetical order. The correct name should be 3-ethyl-3-methylpentane.

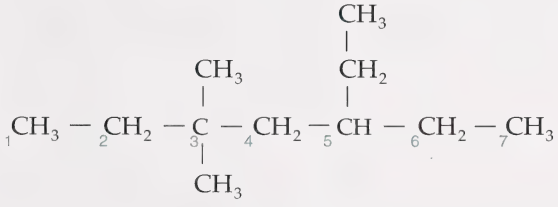
14. a. 3-ethyl-3,4-dimethylhexane



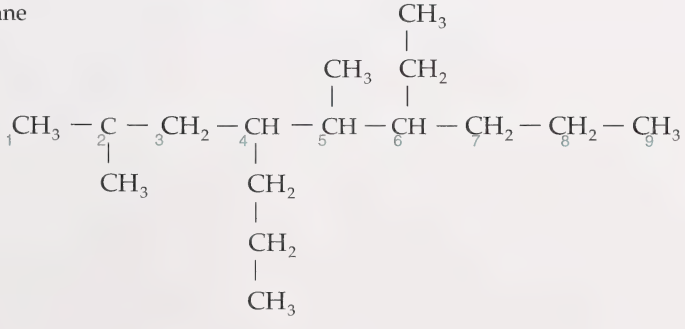
b. 2,2,4-trimethylpentane



c. 5-ethyl-3,3-dimethylheptane



d. 6-ethyl-2,5-dimethyl-4-propylnonane



15. The molecular formula for cyclohexane is C_6H_{12}. Cyclohexane, C_6H_{12}, has two fewer hydrogen atoms than hexane, C_6H_{14}. This is because the two hydrogen atoms must be removed to free up two bonding electrons for the end carbon atoms to form a bond and close the ring.

16. a. cyclopentane b. cyclooctane

17. The traffic device that uses the cyclooctane symbol is the stop sign.

Section 1: Activity 3

1. a. The term used to describe alkanes was homologous series. This term also fits each of the alkene and alkyne families. Each successive member of the series also differs by a $-CH_2-$ group.

   b. The first member of the alkene family is ethene, $C_2H_4 \longrightarrow CH_2=CH_2$. The first member of the alkyne family is ethyne, $C_2H_2 \longrightarrow CH \equiv CH$.

   These differ from the first member of the alkane family in that methane, CH_4, only requires one carbon for the first member. Ethene and ethyne both have two carbons because that is the minimum required to show a double or triple bond.

2. All alkene compounds (double bonds) have names ending in *-ene*. All alkyne compounds have names ending in *-yne*.

3. All alkane, alkene, and alkyne names use the same prefixes to indicate the same number of carbons in their chains.

4. A bromine diagnostic test will distinguish an alkane from an alkene. The bromine will react with an alkene, resulting in a change of solution colour. No colour change occurs if bromine is added to an alkane.

5. a. C_7H_{14} b. $C_{12}H_{24}$ c. C_8H_{16} d. $C_{14}H_{28}$

6. a. C_5H_8 b. $C_{11}H_{20}$ c. C_9H_{16} d. $C_{15}H_{28}$

7. These molecules are the same—one is the mirror image of the other. Both molecules represent 1-butene.

8. Noncyclic Isomers of C_5H_{10}

$$CH_3-CH_2-CH_2-CH=CH_2$$

$$CH_3-CH_2-CH=CH-CH_3$$

$$\begin{array}{l} \quad CH_3 \\ \quad | \\ CH_3-CH-CH=CH_2 \end{array}$$

$$\begin{array}{l} \quad\quad CH_3 \\ \quad\quad | \\ CH_3-C=CH-CH_3 \end{array}$$

$$\begin{array}{l} \quad\quad\quad CH_3 \\ \quad\quad\quad | \\ CH_3-CH_2-C=CH_2 \end{array}$$

Noncyclic Isomers of C_5H_8

$$CH \equiv C - CH_2 - CH_2 - CH_3$$

$$CH_3 - C \equiv C - CH_2 - CH_3$$

$$CH \equiv C - \underset{\displaystyle CH_3}{\underset{|}{CH}} - CH_3$$

9. When alkenes or alkynes are named, the parent chain is numbered from the end that gives the multiple bond the lowest locating number. If the multiple bond gets an equal number if numbered from either end of the parent chain, (the bond is in the middle) then the branches determine the end from which to number. In other words, the chain is numbered from the end that gives the branches the lowest locating numbers.

10. The position of the multiple bond is indicated by the number of the lowest carbon to which it is attached.

11. a. 3-hexene $\overset{1}{CH_3} - \overset{2}{CH_2} - \overset{3}{CH} = \overset{4}{CH} - \overset{5}{CH_2} - \overset{6}{CH_3}$

b. 3-propyl-2-heptene

$$\overset{7}{CH_3} - \overset{6}{CH_2} - \overset{5}{CH_2} - \overset{4}{CH_2} - \overset{3}{\underset{\displaystyle CH_2}{\underset{|}{C}}} = \overset{2}{CH} - \overset{1}{CH_3}$$
$$\begin{array}{l} | \\ CH_2 \\ | \\ CH_2 \\ | \\ CH_3 \end{array}$$

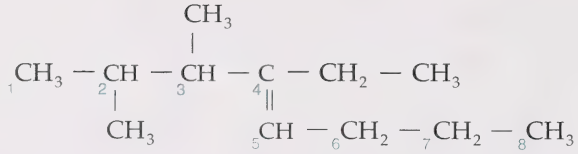
c. 4,4-dimethyl-2-pentyne

$$\overset{5}{CH_3} - \overset{4}{\underset{\displaystyle CH_3}{\underset{|}{\underset{|}{C}}}} - \overset{3}{C} \equiv \overset{2}{C} - \overset{1}{CH_3}$$

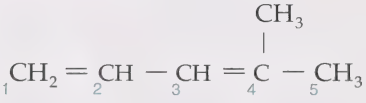
d. 3-ethyl-5-methyl-3-propyl-1-hexyne

$$\begin{array}{l} \qquad\qquad\qquad\qquad\quad CH_3 \\ \qquad\qquad\qquad\qquad\quad | \\ \qquad\qquad\quad \underset{\displaystyle CH_3}{\underset{|}{CH}} \qquad\quad CH_2 \\ \qquad\qquad\qquad\quad | \qquad\quad | \\ \overset{6}{CH_3} - \overset{5}{CH} - \overset{4}{CH_2} - \overset{3}{C} - \overset{2}{C} \equiv \overset{1}{CH} \\ \qquad\qquad\qquad\quad | \\ \qquad\qquad\qquad\quad CH_2 \\ \qquad\qquad\qquad\quad | \\ \qquad\qquad\qquad\quad CH_2 \\ \qquad\qquad\qquad\quad | \\ \qquad\qquad\qquad\quad CH_3 \end{array}$$

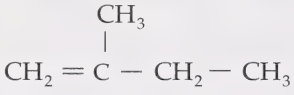
e. 4-ethyl-2,3-dimethyl-4-octene



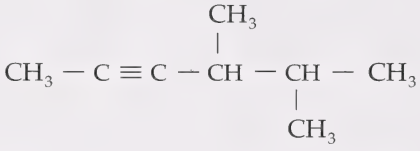
f. 4-methyl-1,3-pentadiene



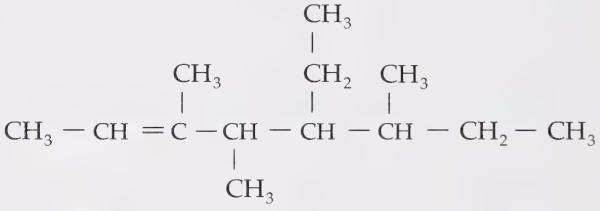
12. a. 2-methyl-1-butene



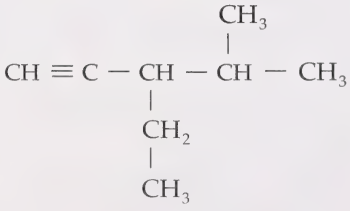
b. 4,5-dimethyl-2-hexyne



c. 5-ethyl-3,4,6-trimethyl-2-octene

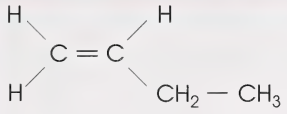
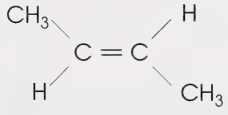
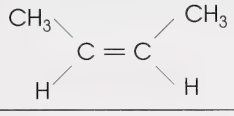
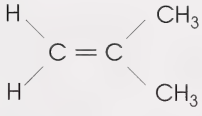


d. 3-ethyl-4-methyl-1-pentyne



13. Natural gas is such an important nonrenewable resource because it is the starting material for producing many other chemical compounds and products.

14. a. The isomers of C_4H_8 may be shown as follows:

Molecular Formula	Structural Diagram	IUPAC Name	Melting Point (°C)	Boiling Point (°C)
C_4H_8		1-butene	-185.3	- 6.3
C_4H_8		trans-2-butene (*Trans* means the $-CH_3$ molecules are on opposite sides of C = C.)	-105.5	0.9
C_4H_8		cis-2-butene (*Cis* means the $-CH_3$ molecules are on same side of C = C.)	-138.9	3.7
C_4H_8		2-methyl-1-propene (methylpropene)	-140.3	- 6.9
C_4H_8		cyclobutane	- 50	12
C_4H_8		methylcyclopropane	-117.2	4-5

Note: You will not be responsible for drawing or naming cis and trans isomers beyond this investigation.

b. The isomers of C_4H_6 may be shown as follows:

Molecular Formula	Structural Diagram	IUPAC Name	Melting Point (°C)	Boiling Point (°C)
C_4H_6	$CH \equiv C - CH_2 - CH_3$	1-butyne	-125.7	8.1
C_4H_6	$CH_3 - C \equiv C - CH_3$	2-butyne	- 32.2	27
C_4H_6		cyclobutene	2	no value found

Cyclopropenes would not exist because of the stress on the bonds.

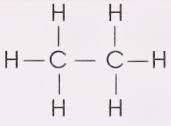
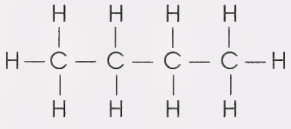
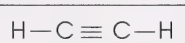
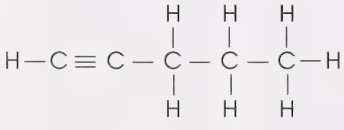
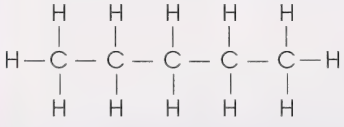
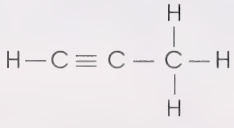
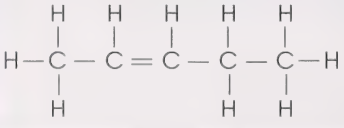
15. You learned in Module 5 that molecular shape, polarity, and size had a great bearing on melting and boiling points. In this case, the size and polarity of the molecules are the same, so size and polarity should not be a factor. That leaves shape. The different shapes of the molecules have an effect on the melting and boiling points.

    For example, the 1-butene and 2-butene isomers (either isomer) have different shapes due to the different positions of the double bond. The 1-butene molecules would probably not stack as closely to each other. This would reduce the intermolecular forces, which reduces the melting point.

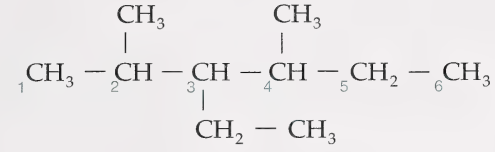
Section 1: Follow-up Activities

Extra Help

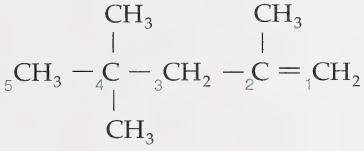
1.

Molecular Formula and Name	Complete Structure	Condensed Structure
a. C_2H_6		$CH_3 - CH_3$
b. C_4H_{10}		$CH_3 - CH_2 - CH_2 - CH_3$
c. C_2H_2		$CH \equiv CH$
d. C_5H_8		$CH \equiv C - CH_2 - CH_2 - CH_3$ or $CH_3 - C \equiv C - CH_2 - CH_3$
e. C_5H_{12}		$CH_3 - CH_2 - CH_2 - CH_2 - CH_3$
f. C_3H_4		$CH \equiv C - CH_3$
g. C_5H_{10}		$CH_3 - CH = CH - CH_2 - CH_3$ or $CH_2 = CH - CH_2 - CH_2 - CH_3$

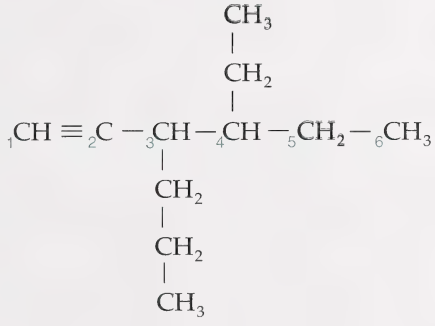
2. a. 3-ethyl-2,4-dimethylhexane



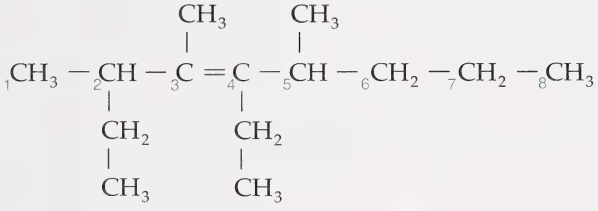
b. 2,4,4-trimethyl-1-pentene



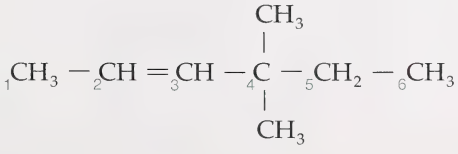
c. 4-ethyl-3-propyl-1-hexyne



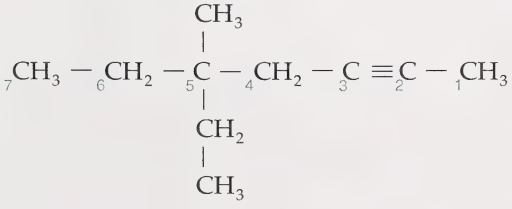
d. 2,4-diethyl-3,5-dimethyl-3-octene



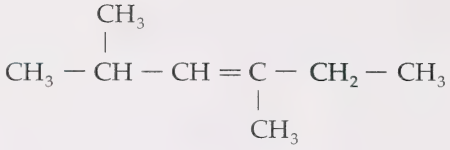
e. 4,4-dimethyl-2-hexene



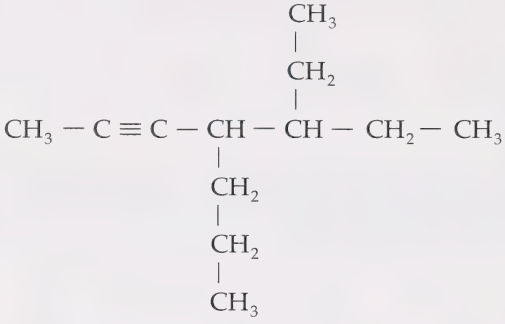
f. 5-ethyl-5-methyl-2-heptyne



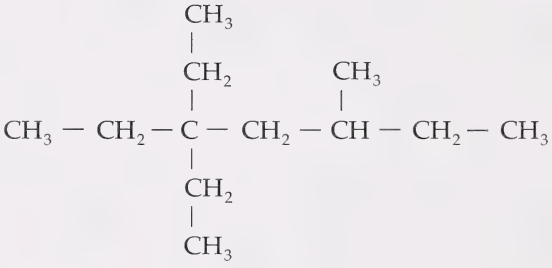
3. a. 2,4-dimethyl-3-hexene



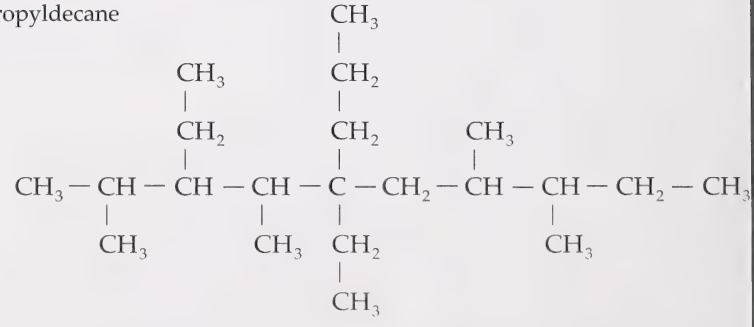
b. 5-ethyl-4-propyl-2-heptyne



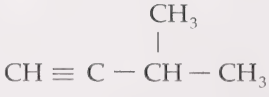
c. 3,3-diethyl-5-methylheptane



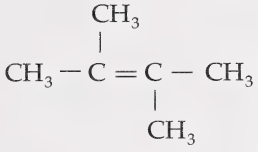
d. 3,5-diethyl-2,4,7,8-tetramethyl-5-propyldecane



e. 3-methyl-1-butyne



f. 2,3-dimethyl-2-butene



Enrichment

1. Answers may vary but could include the following technological methods used to remove H_2S from sour natural gas:

    - It can be removed from a stream of natural gas by compression, drying, condensation, and fractional distillation (Stauffer process).
    - It can be absorbed from sour gas by dissolving it in monoethanolamine aqueous solutions and separating it with steam heat.
    - It can be absorbed from sour gas by dissolving it in hot potassium carbonate aqueous solutions and separating it with steam heat.

    In general H_2S is absorbed and separated by washing and scrubbing the gas mixture with a suitable liquid solvent or having it react chemically with solvents to form chemical complexes that decompose after separation.

2. Answers may vary but could include the following ideas:

    - Ethane is removed from sweet natural gas in extraction plants located near gas wells.
    - Some Alberta plants that cool and compress natural gas to remove ethane are located in Cochrane, Empress, and Edmonton.
    - In Joffre (near Red Deer) ethene is produced by cracking ethane or removing hydrogen (dehydrogenation).
    - Ethene (ethylene) is stored in caverns near Fort Saskatchewan.
    - Ethene uses include the manufacture of ethylene glycol (radiator antifreeze), tetraethyl lead for gasoline, polystyrene and polyvinyl chloride plastics, insecticides, latex, and synthetic rubber.

Section 2: Activity 1

1. Many compounds were originally called aromatics because they emitted odours.

2. Rather than its fragrance, if any organic hydrocarbon has a benzene ring, or a structure similar to the benzene ring, it is considered to be an aromatic.

3. The molecular formula for benzene is C_6H_6.

4. Aliphatics are open-chain or cyclic hydrocarbons containing single, double, or triple bonds, whereas aromatics are compounds that contain the special ring structure of benzene.

5. Benzene molecule 2 is the mirror image of benzene molecule 1.

6. Kekulé proposed that the benzene molecule was cyclic with alternating single and double bonds. Since single and double bonds have different bond lengths, Kekulé's model was incorrect as evidence seems to indicate that all carbon-carbon bonds in benzene are the same length.

7. As shown in Figure 6.4, the hybrid structure of the benzene molecule indicates that the structure of benzene is somewhere in between molecule 1 and molecule 2.

8. Toluene, xylene, and styrene are called arenes because they are all organic compounds containing an aromatic ring.

9. Xylene has the molecular formula $C_6H_4(CH_3)_2$, or C_8H_{10}.

10. The following chart lists some of the potential hazards and benefits of benzene compounds.

Benefits	Hazards
• They provide many types of medicines. • Some provide synthetic materials which, in turn, relieve some pressure on natural resources. • They provide materials such as Styrofoam for insulation.	• Some are potential carcinogens. • Some are toxic and poisonous. • Some may harm the environment. • Some are dangerous because of their explosive threat. • Some cause disposal problems.

11. The molecular formula for naphthalene is $C_{10}H_8$.

12. a. The NO_2 is called a nitro group. b. The NH_2 is called an amino group.

13. a. The molecules in the table are similar in that all are aromatic compounds or contain a benzene ring.

    b. The molecules in the table are different from each other because they all have different kinds of arrangements of bonded atoms to the benzene ring (different functional groups).

Section 2: Activity 2

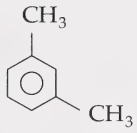
1. An alkylbenzene name is given to an aromatic to which an alkyl group is bonded to a benzene ring.

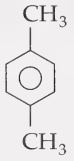
2. An alkyl group replaces a hydrogen atom in an alkylbenzene molecule.

3. Three isomers are possible when two hydrogen atoms are replaced by two alkyl groups.

4. The name 1,2-dimethylbenzene is correct because it assigns the lowest possible numbers to the methyl branches.

5. Two other possible isomers for a molecule containing the benzene ring and two bonded methyl groups are the following:

   • 1,3-dimethylbenzene 

   • 1,4-dimethylbenzene 

6. a. The prefix *ortho-* or *o-* is used for the 1,2 disubstitution pattern.

   b. The prefix *meta-* or *m-* is used in the 1,3 disubstitution pattern.

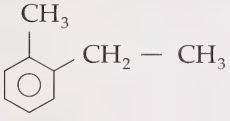
   c. The prefix *para-* or *p-* is used in the 1,4 disubstitution pattern.

7. a. methylbenzene b. ethylbenzene c. propylbenzene

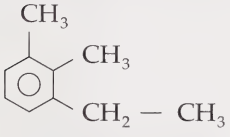
8.

Molecular Structure	IUPAC Name	Classical Name
a.	1,3-dimethylbenzene	m-dimethylbenzene
b.	1,4-diethylbenzene	p-diethylbenzene
c.	1-ethyl-3-propylbenzene	m-ethylpropylbenzene
d.	1-ethyl-4-propylbenzene	p-ethylpropylbenzene

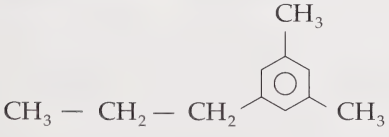
9. a. 1-ethyl-2-methylbenzene



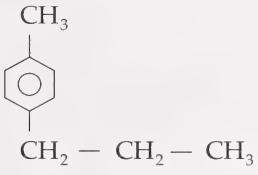
   b. 1-ethyl-2,3-dimethylbenzene



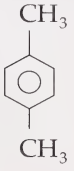
   c. 1,3-dimethyl-5-propylbenzene



   d. 1-methyl-4-propylbenzene



   e. paradimethylbenzene



10. When a benzene ring is considered to be similar to an alkyl branch rather than the parent chain it is called a phenyl group.

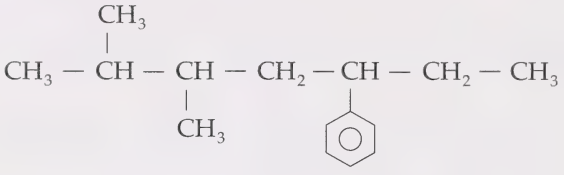
11. a. 2-methyl-2-phenylpentane

    b. 4-methyl-2,4-diphenylhexane

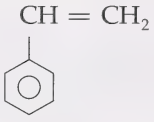
    c. 2-phenylbutane

    d. 3-ethyl-4-methyl-2-phenyloctane

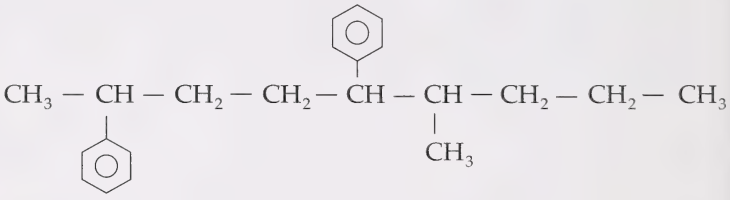
12. a. 2,3-dimethyl-5-phenylheptane



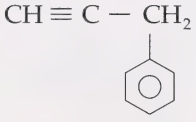
    b. 1-phenyl-1-ethene



    c. 6-methyl-2,5-diphenylnonane



    d. 3-phenyl-1-propyne



Section 2: Follow-up Activities

Extra Help

1. C

2. A

3. B

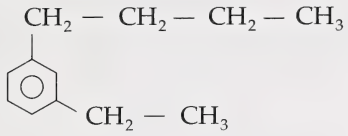
4. a. The compound is 2-phenylpentane.

    b. The compound is 4-methyl-3-phenyl-1-hexene.

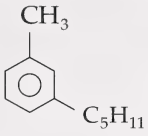
    c. The compound is butylbenzene (1-phenylbutane).

5. The compound can be named 1,4-dipropylbenzene **or** p-dipropylbenzene.

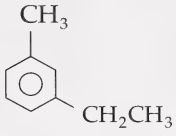
6. a. 1-butyl-3-ethylbenzene



b. 1-methyl-3-pentylbenzene



c. m-ethylmethylbenzene



Enrichment

1. Answers may vary but could include the following points.

Benzene

- produced from petroleum or by heating coal tar and condensing its vapour
- poisonous colourless liquid aromatic with pleasant odour
- has a resonance or hybrid ring structure
- melts at 5.5°C and boils at 80.1°C
- used to produce synthetic rubber and detergents, aniline dyes, nylon, polystyrene and Styrofoam plastics, drugs
- found in bitter almonds (benzaldehyde), oil of wintergreen, ASA, TNT, varnish, etc.
- widely used as a solvent for rubber, gums, fats, resins

Aniline

- a colourless, oily, poisonous benzene derivative
- widely used in the manufacture of rubber, synthetic dyes, resins, pharmaceuticals, varnishes

Toluene

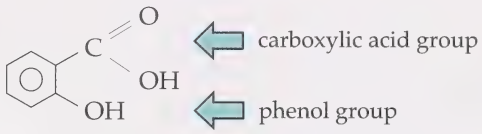
- colourless flammable liquid obtained from coal tar or petroleum
- used in aviation and high octane fuel and as a solvent for oils, paints, gums, resins, vinyl, rubber, and lacquers
- used to make explosives, dyestuffs, enamels, plastic and model airplane adhesive, medicines, dyes, perfumes

Xylene

- three possible flammable benzene derivative isomers – ortho-, meta-, and paraxylene
- obtained from wood and coal tar
- used to make protective coatings, lacquers, enamels, rubber cement, alkyd resin solvent, and aviation fuel

2. Molecular models of benzene, aniline, toluene, or xylene should reflect the structures illustrated in Figure 6.5 and 6.6 of the module.

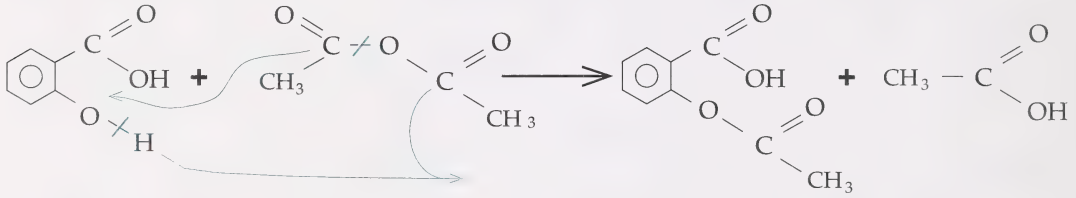
3. The first indication of acetylsalicylic acid, ASA, was in the form of salicylic acid. Salicylic acid was first discovered in white willow bark in the 1700s. Chewing the bark or making a tea from the bark and drinking it seemed to have pain-killing abilities. The pain-killing compound was isolated about seventy-five years after its discovery.



Salicylic Acid

Salicylic acid was used to treat the symptoms of typhoid because it lowered the patient's fever and helped to relieve pain, even though it didn't cure the disease.

Salicylic acid, though, had a side effect in that it was corrosive to the mucous membranes in the mouth and stomach. A German chemist working for the Bayer company was able to improve the analgesic (pain killer) by reacting salicylic acid with acetic anhydride – hence the birth of acetylsalicylic acid, ASA, under the brand name of Aspirin®.



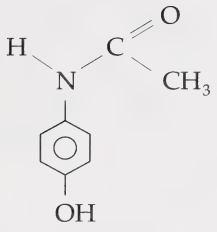
salicylic acid | acetic anhydride | acetylsalicylic acid (ASA) | acetic acid

ASA is effective in two main areas: it reduces swelling (anti-inflammatory) and it relieves pain (analgesic). In this way it alleviates the symptoms of many diseases, but does not cure the diseases themselves.

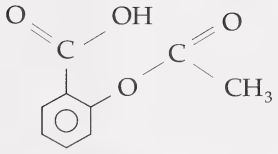
ASA works by blocking the production of complex molecules called *prostaglandins*. These molecules warn the body of injury and mediate body temperature under the invasion of disease. ASA is especially useful for diseases such as rheumatoid arthritis which causes pain and swelling in the joints – mainly fingers. Societies world-wide consume in the order of 100 000 tonnes of ASA per year.

ASA does have some side effects for some people by causing stomach discomfort. Chronic users may even reduce the mucous lining of the stomach and upper intestine to the extent that an ulcer develops.

Since the discovery of ASA, several other related analgesics have been developed, one of which is acetaminophen.



acetaminophen



acetylsalicylic acid

As you can see, both compounds are aromatic. Both are also metabolized in the body in a similar manner. Acetaminophen is similar to ASA in its relief of pain and fever reduction. However, acetaminophen does not reduce inflammation.

The video ends with a moral question for you to consider. As evidenced by the fact that ASA was initially discovered in its elementary form in the bark of a tree, is it a good idea to continue to fell forests at an alarming rate? Will the natural sources of as yet undiscovered drugs be forever eliminated?

Section 3: Activity 1

1. The halogens (F, Cl, Br, and I) distinguish the organic halides from other derivatives. Examples will vary, e.g., CFCs.

2. Common halides are compounds such as the freons, Teflon®, DDT, and PCBs.

3. Freons are CFCs commonly used as refrigerants in refrigerators and air conditioners and formerly as propellants in spray can products.

4. As organic halides, CFCs would be organic compounds in which one or more hydrogen atoms have been replaced by halogen atoms.

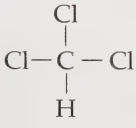
5. Besides destroying the ozone layer, many organic halides may also be toxic or carcinogenic.

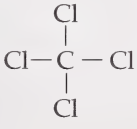
6. By monitoring CFC concentrations in the atmosphere it was noted that decreasing ozone levels and increasing levels of CFCs seemed to be related.

7. a. The prefix (*fluoro-*, *chloro-*, *bromo-*, or *iodo-*) in the name tells you that the substance is an organic halide.

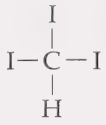
   b. The F, Cl, Br, or I atoms in the structure indicate that the substance is an organic halide.

8. The condensed structural diagrams of the organic halides are as follows:

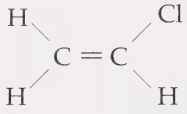
a.


b.


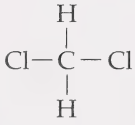
c.



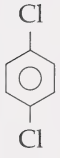
d.



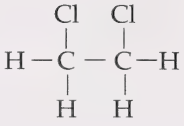
e.



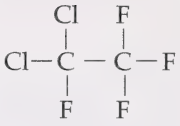
f.



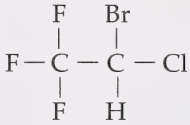
g.



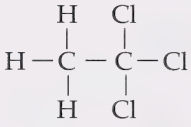
h.



i.



j.

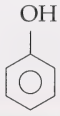


9. A functional group is an atom, a group of atoms, or a special bond arrangement that gives a compound its physical and chemical properties.

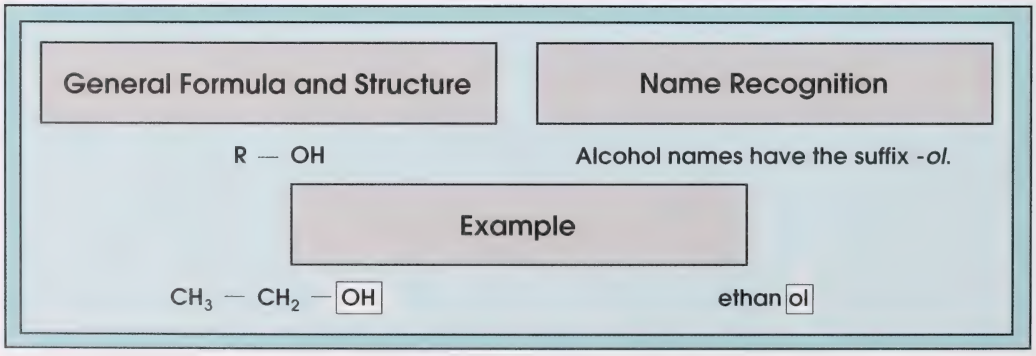
10. Properties of alcohols that can be explained due to the hydrogen bonding which they possess include a very high water solubility for shorter chain alcohols and low volatility.

11. Alcohols are widely used as industrial solvents because they can dissolve many organics – shorter chain alcohols are polar and long chain alcohols are non-polar.

12. The structural diagram for phenol is



13.



14. a. The suffix *-ol* in the name tells you that the substance is an alcohol.

    b. The hydroxyl group, — OH, in the structure tells you that the substance is an alcohol.

15. The condensed structural diagrams of the alcohols are shown here.

    a. $CH_3 - OH$

    b. $CH_3 - CH_2 - OH$

    c. $CH_3 - CH_2 - CH_2 - OH$

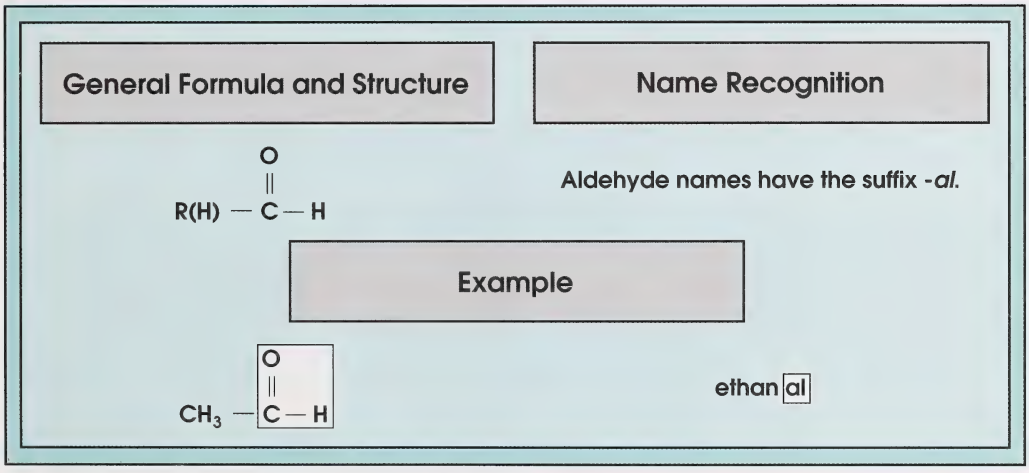
    d. $CH_3 - \underset{\displaystyle OH}{\underset{|}{CH}} - CH_3$

    e. $CH_3 - \underset{\displaystyle OH}{\underset{|}{CH}} - CH_2 - CH_3$

    f. $CH_3 - CH_2 - CH_2 - CH_2 - CH_2 - OH$

Section 3: Activity 2

1.



2. a. The *-al* suffix in the name tells you that the structure is an aldehyde.

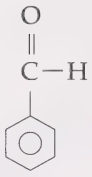
   b. The functional group $- \underset{\displaystyle O}{\underset{\|}{C}} - H$ on one end of the structure tells you that the substance is an aldehyde.

3. A sharp, irritating odour could be used to identify smaller aldehydes but other tests would be needed to confirm that it is indeed an aldehyde; other types of compounds can also have sharp odours.

4. Methanal or formaldehyde is now used to manufacture Bakelite® plastic. It was used at one time to preserve biological specimens.

5. Ethanal or acetaldehyde is now used to produce other organic compounds such as acetic acid.

6. The structural formula for benzaldehyde is



7. The condensed structural diagrams of the various aldehydes are as follows:

a. $H-\overset{\overset{O}{\|}}{C}-H$

b. $CH_3-\overset{\overset{O}{\|}}{C}-H$

c. $CH_3-CH_2-\overset{\overset{O}{\|}}{C}-H$

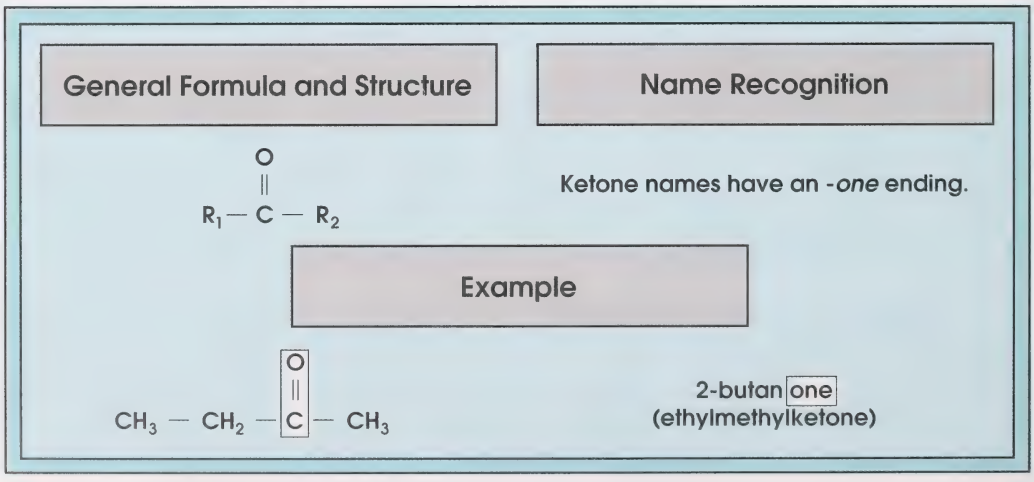
d. $CH_3-CH_2-CH_2-\overset{\overset{O}{\|}}{C}-H$

8. Ketones differ from aldehydes only by the position of the carbonyl functional group on the hydrocarbon chain. The ketone carbonyl group is somewhere in the inside of the structure with carbon atoms on both sides. The carbonyl group is at one end of the structure in an aldehyde.

9. The chemical reactivity is affected by the position of a carbonyl group in ketones.

10. The simplest ketone is propanone (also called acetone) found in nail polish remover, plastic glues, resins, and varnishes.

11.



12. a. The *-one* ending on the name tells you that the substance is a ketone.

b. The carbonyl group, C = O, in the inside of the structure tells you that the substance is a ketone.

Section 3: Activity 3

1. Carboxylic acids contain the carbonyl, C = O, and hydroxyl, — OH, functional groups.

2. The common sources of carboxylic acids are foods such as citrus fruits, crabapples, and rhubarb.

3. A lemon is a citrus fruit containing carboxylic acid which has a sour tangy taste not found in a banana.

4. Two common carboxylic acids properties include the following:

   - They possess a solubility similar to alcohols arising from polar hydrogen bonding for smaller molecules.
   - They change blue litmus to red.

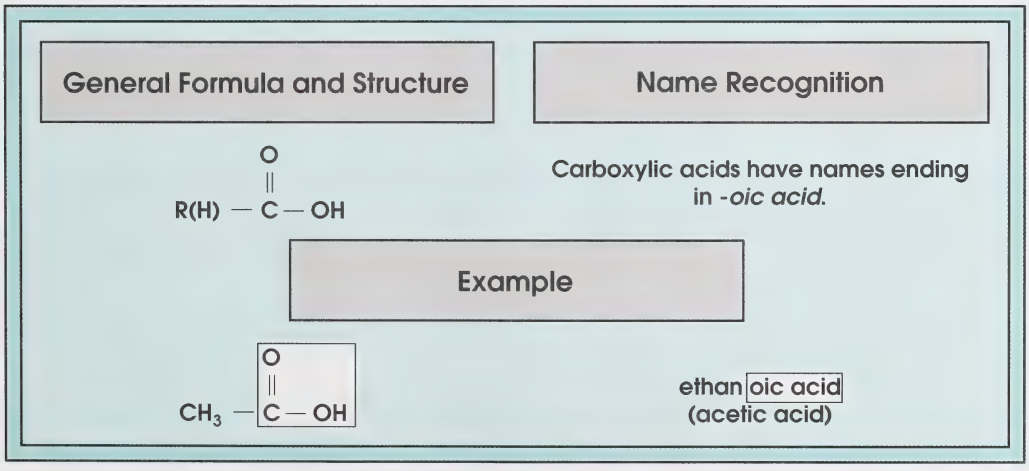
5. Litmus paper can be used to identify carboxylic acids; blue litmus turns red.

6. One common use for methanoic or formic acid includes the removal of hair from hides during tanning. It is also used to coagulate and recycle rubber.

7. Oxalic acid contains two carboxyl functional groups, is found in sorrel and rhubarb leaves, and is used as a rust remover and cleaner of copper and brass. Tartaric acid contains two carboxyl and hydroxyl functional groups, is found in grapes, and is used to make crystal fruit drinks. Citric acid contains three carboxyl groups and one hydroxyl functional group, is found in citrus fruits, and is used in making soft drinks.

8. People produce trace amounts of carboxylic acids on their skin which differ in chemical composition from person to person. Tracking dogs, with a highly developed sense of smell and sensitivity to odours, are able to detect the slight difference in scents produced by individuals.

9.



10. a. The *-oic acid* ending on the name tells you that the substance is a carboxylic acid.

    b. The — COOH functional group in the structure tells you that the substance is a carboxylic acid.

11. The condensed structural diagrams for the given carboxylic acids are as follows:

a. $H-\overset{\overset{O}{\|}}{C}-OH$

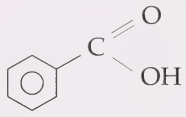
b. $CH_3-\overset{\overset{O}{\|}}{C}-OH$

c. $CH_3-CH_2-\overset{\overset{O}{\|}}{C}-OH$

d. $CH_3-CH_2-CH_2-\overset{\overset{O}{\|}}{C}-OH$

e. $CH_3-CH_2-CH_2-CH_2-\overset{\overset{O}{\|}}{C}-OH$

f. $CH_3-CH_2-CH_2-CH_2-CH_2-\overset{\overset{O}{\|}}{C}-OH$

g. 

12. Esters differ from carboxylic acids in that the hydrogen atom from the hydroxyl group is replaced by a hydrocarbon branch. Ester functional groups are inside a structure; carboxylic acid functional groups are on the end of a structure.

13. Esters are responsible for the odours of fruits and flowers.

14. Common uses for esters include their use in foods, perfumes, and cosmetics to enhance aroma or taste. They are also used as solvents and for the making of synthetic fibres such as polyester.

15. The first part of an ester name refers to the alcohol used in making the ester. The second part of the name comes from the acid by changing the *-oic acid* ending to *-oate*.

16.

General Formula and Structure

$R_1(H)-\overset{\overset{O}{\|}}{C}-O-R_2$

Name Recognition

Ester names have an *-oate* ending.

Example

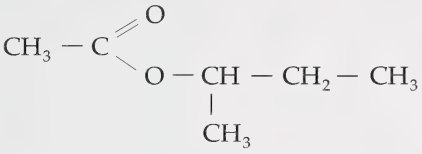
$CH_3-\overset{\overset{O}{\|}}{C}-O-CH_3$

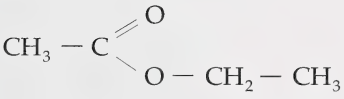
methyl ethan**oate**

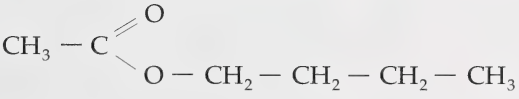
17. a. The *-oate* ending on the name tells you that the substance is an ester.

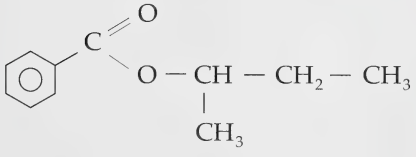
b. The $-\overset{\overset{O}{\|}}{C}-O-$ functional group in the structure, with an alkyl (carbon) group attached to the oxygen, indicates that the substance is an ester.

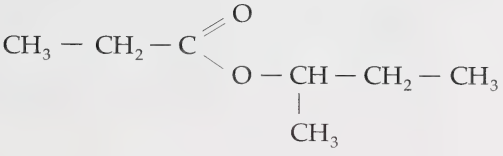
18. The condensed structural diagrams for the given esters are as follows:

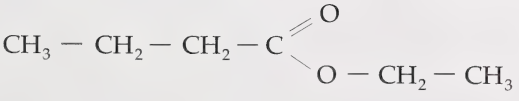
a.


b.


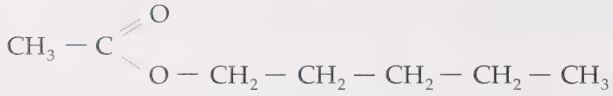
c.


d.


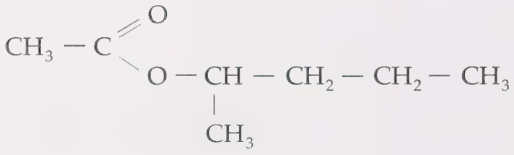
e.


f.


g.



h.



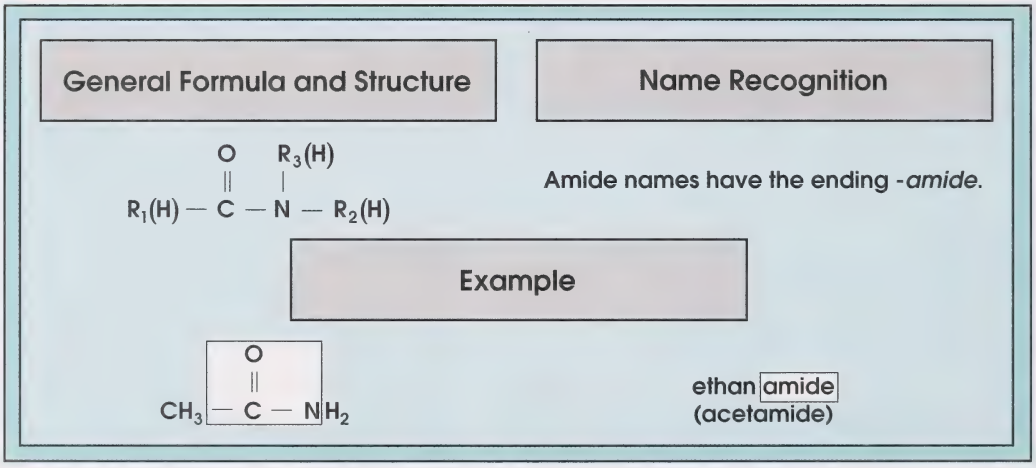
Section 3: Activity 4

1. a. The amide functional group consists of a carbonyl group bonded to a nitrogen atom.

   b. The amide functional group is usually found or occurs in proteins.

2. A peptide bond is an amide link which joins amino acids together in proteins.

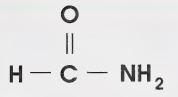
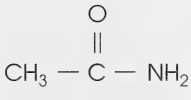
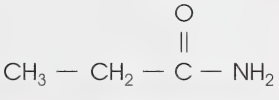
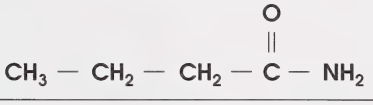
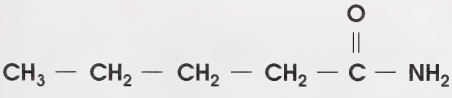
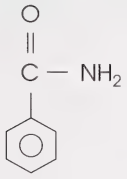
3.



4. a. The *-amide* ending of the name indicates that the substance is an amide.

   b. The functional group in the structure tells you that the substance is an amide.

5.

IUPAC Name (common name in brackets)	Structural Formula	Typical Technological Uses and Comments
a. methanamide (formamide)		• intermediate in organic synthesis • solvent, softener
b. **ethanamide** (acetamide)		• wetting agent (allows liquid to spread over or penetrate into surface) • used in lacquers and explosives
c. **propanamide** (propionamide)		• N/A
d. butanamide (butyramide)		• N/A
e. pentanamide (valeramide)		• N/A
f. **benzamide**		• organic synthesis

6. a. There is one hydrocarbon group bonded to the central N atom in a primary amide.

   b. There are two hydrocarbon groups bonded to the central N atom in a secondary amide.

   c. There are three hydrocarbon groups bonded to the central N atom in a tertiary amide.

7. The structure of an amine could be described as a molecule having one or more hydrocarbon groups bonded to a nitrogen atom.

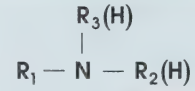
8. Some properties common to amines are their unpleasant odours, high water solubility, strong hydrogen bonding, and polarity.

9. The number of alkyl groups or hydrocarbon residues bonded to the central N atom are as follows:

   a. 1 b. 2 c. 3

10.

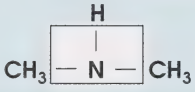
General Formula and Structure



Name Recognition

Amine names have the ending *-amine*.

Example



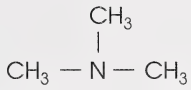
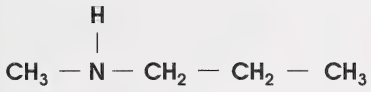
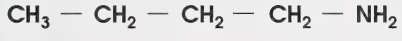
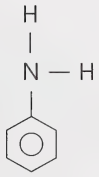
dimethyl**amine**

11. a. The suffix *-amine* on the end of the name indicates that the substance is an amine.

    b. The nitrogen atom attached to one or more alkyl groups in the structure indicates that the substance is an amine.

12.

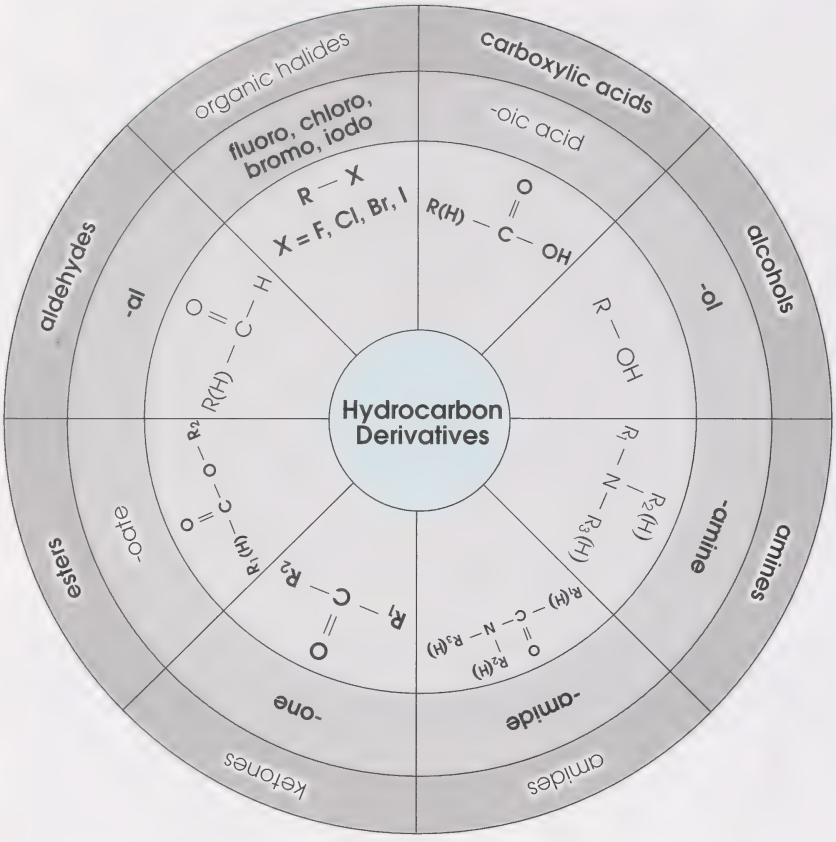
IUPAC Name	Condensed Structural Formula	Typical Technological Uses and Comments
a. **methylamine**	$CH_3 — NH_2$	• flammable gas, solvent • used in producing dyes and insecticides
b. ethylamine	$CH_3 — CH_2 — NH_2$	• colourless, volatile liquid • used in petroleum refining, detergents, organic synthesis
c. diethylamine	$CH_3 — CH_2 — \underset{\displaystyle H}{N} — CH_2 — CH_3$	• rubber chemicals, textiles and dyes, pesticides, drugs, electroplating

d. dimethylamine		• gas absorbent, solvent, textile chemicals, rocket propellant, missile fuel
e. **trimethylamine**		• insect attractant, organic synthesis of disinfectants, plastics
f. methylpropylamine		• N/A
g. butylamine		• intermediate emulsifying (light-sensitive coating) and tanning agent • makes dyes, drugs, insecticides
h. **phenylamine**		• oily, colourless, poisonous benzene derivative • used to make rubber, dyes, resins, varnishes, pharmaceuticals

Section 3: Follow-up Activities

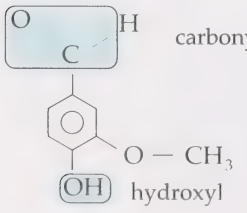
Extra Help

1.



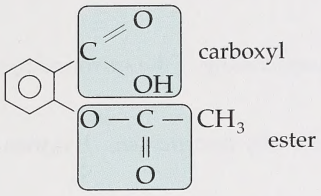
2. **Textbook question 20:**

a.



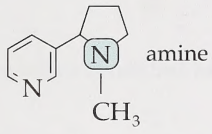
vanillin
use: flavouring for foods

b.



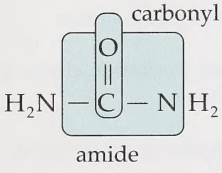
acetylsalicylic acid (ASA)
use: reduces aches and pain, inflammation, fever

c.



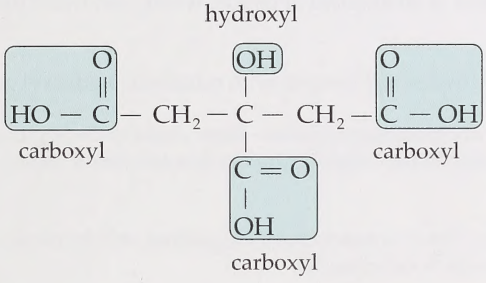
nicotine
source: tobacco

d.



urea
source: animals, fertilizer

e.



citric acid
source: citrus fruits

Enrichment

1. Answers may vary but could include the following main ideas about the function and use of freons:

   - Freons are trademarks for a wide variety of volatile (easily evaporated), nonflammable liquid or gaseous chlorofluorocarbons used as fluids in refrigeration systems, air conditioners, and aerosol propellants.
   - Freon is relatively nonreactive under normal room conditions and can be mixed with a variety of materials and may also be used as an aerosol. The problems start when the freons reach the upper atmosphere.
   - Freons can be readily changed from a liquid to gaseous state or a gaseous to liquid state at normal room temperatures by changes in pressure.

- The cooling process works in the following manner:
  - When a liquid changes to a gas, heat is required, which causes cooling of the surroundings from which it is obtained.
  - Gaseous freon can be readily changed back into the liquid state by compression. It is then ready to repeat the cooling process.

2. Answers may vary but could include the following ideas on the production and uses of ethanol:
   - It is a colourless, volatile, and flammable liquid.
   - It can be synthesized in a number of ways or made by fermentation of sugars and starch in the presence of a yeast enzyme.
   - Ethanol is the most widely used solvent in pure, diluted, or denatured form (made poisonous to prevent consumption).
   - It is found in intoxicating beverages such as beer, wine, or spirits – usually in diluted form.
   - Ethanol is used in the manufacture of drugs and pharmaceuticals, cosmetics, perfumes, cleaning solutions, explosives, and vinegar. It is also used as a synthetic flavour solvent.
3. Answers may vary but could include the following ideas on the function of aldehydes and ketones in determining the types of carbohydrates:
   - Carbohydrates include sugars, starch, and cellulose (a component of cotton, wood, and wood products such as paper).
   - Carbohydrates are monomers or polymers of aldehydes and ketones with numerous hydroxyl groups.
   - Simple sugars or monomers (one unit molecule) are monosaccharides – these could include glucose (corn, grape, and blood sugar) containing an aldehyde functional group, or fructose (fruit sugar) containing a ketone functional group.
   - Sucrose (table sugar) is a disaccharide formed from two monosaccharides, glucose and fructose, which bond to form a *dimer* (one molecule with two similar bonded units).
   - Starch and cellulose (found in the cell walls of plants) are polysaccharides containing many bonded monosaccharides.
4. Answers may vary but could include the following ideas on amino acids and their function in the formation of proteins:
   - Amino acids contain the amino (NH_2) and carboxyl (COOH) groups in the same molecule.
   - A peptide link involves an amine group of one amino acid bonding with the carboxyl group of another amino acid.
   - A protein is a polypeptide containing several hundred amino acids bonded together.
   - The amino acid sequence in a polypeptide determines the type of protein involved.
   - Proteins are the main components of muscle tissue and enzymes.

© 1993, 2001